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THE STATUS OF THE NATION'S HIGHWAYS AND BRIDGES: CONDITIONS AND PERFORMANCE

REPORT

OF THE

SECRETARY OF TRANSPORTATION

TO THE

UNITED STATES CONGRESS

Pursuant to Sections 307(e) and 144(i) of Title 23, United States Code

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LETTER OF TRANSMITTAL

THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

July 2, 1991

The Honorable Thomas S. Foley
Speaker of the House of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

This letter transmits the 1991 edition of the Status of the Nation's Highways and Bridges: Conditions and Performance report. This document, which is the eleventh in a series of congressionally required biennial reports, provides information on highway and bridge finance, conditions and performance, and future capital investment requirements to achieve defined system performance objectives.

The report establishes performance and financial benchmarks as a point of departure for further analysis. It presents the existing status of the physical conditions and performance level of service on the Nation's public roads and bridges. It also provides systematic estimates of the investment levels required to maintain or to uniformly improve the Nation's highways and bridges to pre-specified improvement levels. It should be noted that these estimates do not constitute policy scenarios as no priorities, environmental, or fiscal constraints have been introduced.

As requested by the House Committee on Public Works and Transportation, this version contains substantive improvements in coverage and analysis procedures in order to facilitate comparisons among conditions and performance estimates, investment requirements, and current spending levels. Analysis procedures have also been modified to reflect the impact of right-of-way constraints on demand and to incorporate a broad array of investment strategies, including systems operations and management as an alternative to traditional highway construction. This combination of changes enhances the report's usefulness as a resource document as the Nation faces the task of reauthorizing the Federal surface transportation programs.

A copy of the report has also been made available to Senators Quentin N. Burdick and John H. Chafee, and Congressmen Robert A. Roe and John Paul Hammerschmidt.

Sincerely,

Samuel K. Skinner

Samuel K. Skinner

Enclosure

The 1991 Status of the Nation's Highways and Bridges: Conditions, Performance, and Capital Investment Requirements

September 1991

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Introduction and Executive Summary

Introduction

Authority

This is the eleventh in a series of congressionally required biennial reports submitted by the Secretary of Transportation to the Congress pursuant to Section 307 of Title 23, United States Code. The report provides objective information on highway and bridge finance, systems, conditions and performance, and investment requirements.

Report Objectives

The objectives of the report are to provide the Congress and other decisionmakers with an ongoing appraisal of:

- current and expected future highway travel demand;
- current highway and bridge finance;
- current physical conditions and operating performance on all roads and bridges; and
- twenty-year capital investment requirement estimates for maintaining or improving the current physical and operating conditions of the Nation's highways and bridges.

Congressionally-Requested Modifications in Scope

In the covering letter prefacing the 1989 edition of this report, the House Committee on Public Works and Transportation requested specific modifications in scope so that "As the Congress begins an extensive review of the national surface transportation policies ... this report should have provided the range of information that will be needed to adequately assess the Nation's transportation needs."

Use of Scenarios

The Committee requested analysis of "a broad array of investment options," including an investment scenario for "the preservation of current conditions and services utilizing a full array of improvement options ... incorporating operational and other non-construction options." The Committee also requested a scenario with "a higher level of capital investment" that would "preserve and improve mobility." This edition of the report provides investment requirement estimates for the two requested scenarios:

- the costs of maintaining the current (1989) overall physical conditions and performance levels on the Nation's nonlocal roads, within the context of anticipated future traffic increases, and

- the costs of improving the conditions and performance on the Nation's nonlocal roads to a specified engineering standard of cost-effectiveness, again, within the context of anticipated future traffic increases.

Analytical models are used to provide estimates of the cost of meeting engineering standards specified for physical conditions and performance level of service in each scenario. Condition and performance deficiencies are treated independently and all classes of highway, administrative jurisdictions, urban or rural locations, receive equal consideration over the entire public road system.

No policy priorities regarding strategic importance of individual facilities or classes of highway are assumed in determining scenario costs, nor have institutional constraints to highway and bridge improvements, such as fiscal capacity or air quality considerations in non-attainment areas. However, certain policy-oriented assumptions have been made, such as reduced rates of travel growth in highly congested urban areas, the application of rigorous supply and demand management strategies prior to estimation of construction costs, and constraints on the amount of new highway capacity in large urban areas.

The scenarios are thus not intended to represent comprehensive alternative national investment policies since, in actual practice, States would apply priorities to focus improvements on selected facilities. Nonetheless, these scenarios provide general financial and performance benchmarks and a basis for development and evaluation of policy and program options.

Expanded Coverage

The Committee indicated that the value of the reports would be enhanced by improving the methods for measuring user costs and congestion effects and providing a means of relating time-series measures of conditions and service levels. This edition of the report has made significant progress in all these areas by:

- realistically simulating travel behavior and usage patterns that typically occur as roads become more congested, including the potential diversion of trips to less congested facilities and the spreading of peak-periods of travel demand;

- incorporating the savings associated with a systematic "congestion management" response to highway travel growth, including diversion to transit or ridesharing and the improved efficiencies of various traffic operation and management strategies;

- providing closer identity between actual current investments and future investment requirements, including (1) cost estimates for new or upgraded highways in response to suburban growth; (2) capital-intensive capacity improvements increasingly undertaken in larger urban areas; (3) capital requirements on local roads; and (4) defense highway requirements.

The Purpose of Highway Capital Investment

Economic competitiveness and quality of life are closely linked to productivity in the Nation's "post-industrial" economy. Considering the degree to which national productivity increasingly depends on fast and reliable transportation, *the ability of the United States to compete successfully in the world marketplace and to continue its standard of living is closely linked to our collective efforts at ensuring adequate transportation systems.* The scale of highway transportation's contribution is conveyed by the following:

- The Nation's 3.9 million miles of public roadway accommodate over 187 million vehicles travelling over 2.1 trillion miles each year.

- Expenditures for highway transportation are equivalent to about 17.5 percent of gross national product (GNP), with almost 85 percent of this, or about 15 percent of GNP, devoted to highway transportation.

- Highway vehicles carry more than 80 percent of domestic intercity passenger miles of travel, and have for every five-year period since World War II.

- The trucking industry carries over one-third of all intercity freight tonnage, earning more than one-half of all revenues of carriers subject to Interstate Commerce Commission regulation.

- In urban areas, automobiles and transit buses account for over 92 percent of all work trips. About 87 percent of all passenger-miles of travel are highway dependent.

- The household budget for vehicle repair and operation, combined with the highway transport cost of goods and services consumed by the household, consumes as much as 18 to 20 percent of the average household's disposable income, *exceeded only by outlays for housing and food.*

The total user cost of highway transportation is made up of two components: (1) the cost to highway users of using the system, including vehicle operating costs, accident costs, and the value of time expended in highway travel and (2) the public cost of highway construction and repair. While other societal costs relating to community, environmental, and energy impacts must be considered, the primary objective of highway capital investment is to minimize the total cost of transportation, including public costs and total user costs incurred by transportation users.

User costs vary directly with both highway physical conditions and system performance. These factors are directly affected by the level of highway investment. From a highway engineering economics perspective, the appropriate level of investment, in turn, depends on the level of system condition and performance desired.Highways in poor condition cost users as much as 25 to 30 percent more per mile than highways in good condition. Highly congested peak-period travel, typical of the Interstate and other freeway operating characteristics in many larger urbanized areas, can add as much as 35 percent to the unit operating and time costs of a commercial vehicle. Every 1 percent increase in highway user costs adds about $15 billion to the Nation's total highway bill, including increased vehicle depreciation and maintenance, fuel, oil, and tire consumption.

Direct public costs (that is, the total highway budget) constitute only about 8 percent of the total costs incurred for highway usage. Approximately 92 percent of total highway costs are accounted for by the vehicle operating costs and value of time expended for travel. While these private costs typically occur in small and regular increments, their cumulative effect on the budgets of households and industry is substantial. The relatively small public investment that improves conditions or performance can have a substantial leveraging effect on the large private cost component.

Highway and bridge condition and performance are functions of current conditions, future travel demand, and capital and maintenance commitments to highway and bridge infrastructure. Adequate future highway service will be determined by how closely capital requirements and commitments match. Although highway agencies have been highly suceessful in addressing the physical deterioration documented throughout the 1970's and early 1980's on both the highway and bridge systems, total investment has not kept pace with all system demands. It is for this reason that system performance has declined. In 1989—

- Approximately 265,000 miles of pavement were at or below accepted engineering standards for cost-effective maintenance.

- Approximately 134,000 bridges were rated as structurally deficient, which means that they were unable to carry safely trucks and buses at the State's legal weight limits or could not carry safely traffic at the speed allowed on the approaching roadway. In 1989, over 5,000 bridges were *closed* to traffic for either structural deficiencies or bridge repair.

- Congestion introduced over 8 billion hours in delay on the Interstate System and other principal arterials, compared to uncongested conditions, adding billions in cost to interstate commerce.

- In the Nation's 39 largest metropolitan areas, the cost of congestion, including costs for delay and fuel consumption, was estimated to be over $34 billion in 1988[1].

The cost of keeping roads and bridges in adequate repair and maintaining modest levels of service is generally much lower than the cost imposed on users by poor conditions and performance, although community and environmental constraints may sometimes alter this equation. It is for this reason that condition and performance assessments and investment requirements estimates are made — to provide a benchmark against which to evaluate the system performance impacts of current and anticipated investment.

Report Organization

This report contains chapters on system characteristics, highway finance, condition and performance measures, and capital investment requirements.

- *Chapter 1* describes recent trends in highway travel and highway system mileage.
- *Chapter 2* outlines highway revenue sources and recent expenditure patterns for all units of government.
- *Chapter 3* describes current highway and bridge conditions and performance and selected trends.
- *Chapter 4* projects future highway travel demand and estimates capital investment requirements.

Each chapter is introduced by a brief summary. Chapter text may reference technical reports that are available under separate cover from the Federal Highway Administration (FHWA). A Glossary of Terms is included at the end of the report.

Scope

Information is included for all of the Nation's roads and bridges, covering all public highway and bridge infrastructure and all privately owned toll facilities. The scope complies with the report's congressional requirements.

The report is developed from data collected at the State level. Information is aggregated to a national perspective with certain information on system condition and performance reported by State. Future travel forecasts used in the estimation of investment requirements were developed by the States. All investment estimates are for the period January 1, 1990, through December 31, 2009, and are expressed in 1989 dollars.

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[1] *Roadway Congestion in Major Urbanized Areas 1982-1988,* Texas Transportation Institute in cooperation with the U.S. DOT and FHWA, 1990.

Data Sources and Analytical Procedures

Finance information is obtained from the FHWA financial reporting system, the same system used in compiling the annual *Highway Statistics*, a report that analyzes statistics of general interest relating to highway transportation.

Condition and performance information is derived from the Highway Performance Monitoring System (HPMS). The HPMS was developed jointly by the Federal and State governments in the late 1970's to provide a continuing source of standardized data on highway conditions and performance. The HPMS includes a statistically drawn sample of 100,000 highway sections, with each sample representing highway type and traffic volume group within each State. These sections represent approximately 1.2 million miles of highway functionally classified as arterials or collectors. Highway sampling ranges — from over 50 percent of Interstate System mileage down to 3 percent of minor collector mileage -- have been selected for statistical validity at the State level, and for aggregation to represent national conditions.

Bridge condition information is obtained from the National Bridge Inventory (NBI). This inventory contains detailed data on the structural, deck condition, and performance characteristics of all bridges and culverts 20 feet or greater in length.

The HPMS and NBI data are updated annually by the States and submitted to FHWA for editing and verification. Information that cannot be verified or that appears to be outside a reasonable range is rechecked with the submitting State. No data submitted by a State are changed without prior State approval. This system is constantly revised and improved. At this time, and as a result of State efforts to refine the database, there are seven years of consistant data (1983–1989) to support time-series condition and performance trend analyses. The first such HPMS data trends are included in this report.

Investment requirements estimates for nonlocal roads were determined using the HPMS Analytical Process, an engineering-based simulation procedure that uses HPMS data to estimate future highway deterioration and the effects of capital improvements. Bridge requirements were estimated using NBI data in conjunction with the Bridge Needs and Investment Process (BNIP), a simulation model similar in design to the HPMS Analytical Process. Local roads are not sampled, although summary information about mileage and travel for them is included in the HPMS. The estimate of capital investment requirements for local roads was developed from information on rural roads published by the U.S. Department of Agriculture, Office of Transportation, and from *Highway Statistics*.

Executive Summary

Highway and Bridge System Characteristics

Functional Systems

The 3.87 million miles of road in the United States are functionally classified as *arterials, collectors*, or *local roads*, depending on the type of service they provide. These broad classifications are further subdivided in rural and urban areas for purposes of system development, description and analysis.

Arterials provide connectivity for longer trips. They generally have higher design standards than other roads, with wider and/or multiple lanes, often with some degree of access control. Arterials connect urban areas, and urban and rural locations that generate significant amounts of travel. *Arterials constitute approximately 10 percent of total highway mileage, but they carry 70 percent of all highway travel.* The Interstate System, which is part of the arterial system, carries approximately 22 percent of total highway travel on 1 percent of total highway mileage.

Collectors are usually two-lane roads that serve shorter trips. They collect and distribute travel to and from the arterial systems. *Collectors accommodate approximately 15 percent of travel on about 21 percent of highway mileage.* They often provide the highest degree of mobility available or needed for a variety of local travel requirements.

Local roads, which account for approximately 69 percent of mileage, carry about 15 percent of travel. They provide the land access function.

Functional Systems and Tripmaking

Highway "systems" are comprised of functional classes working together to provide efficient vehicle movement. A typical highway trip begins on either a collector or a local road, then moves onto an arterial route for the line-haul portion of the trip. This allows the vehicle to take advantage of the arterial's higher speeds and more direct connections between towns and cities or, in the case of a purely urban trip, between areas of the city. Because of the higher design characteristics of arterials, particularly the control of access, the travel time, accident rate and vehicle operating cost per-mile are usually lower for the portion of the trip made on the arterial than for the portion made on the collector or local road.

Incomplete networks, poor physical conditions, or serious congestion on higher level systems lead to greater use of lower level systems and result in less efficient, longer, slower and more expensive trips. These factors may also generate incompatibilities among the transportation system and adjacent land uses; for example, when commuters or trucks use local residential streets to avoid a highway facility that is congested.

Jurisdictional Responsibility

Functional class is not necessarily an indication of highway ownership (Exhibit 1). Nationwide, States have jurisdictional responsibility for approximately 800,000 of the 3.9 million miles of road. The Federal Government has responsibility for approximately 184,000 miles, primarily in national parks, forests, and Indian reservations. Local governments retain control of, and responsibility for, the remaining 2.9 million miles, although State/local agreements may authorize States to construct and maintain locally controlled roads under a cooperative reimbursement agreement. There is no consistent relationship between functional systems and jurisdictional responsibility although, as a general rule, States control the higher functional systems and local governments control lower systems.

System Mileage and Travel

The rate of growth in highway vehicle travel has exceeded 3.0 percent for every five-year period since 1960, except for the recession years in the early 1980's. Over the last six years it has averaged almost 4.2 percent annually — a rate that would double travel in less than 20 years. There are now over 2.1 trillion

Exhibit 1
1989 Mileage by Functional System and Jurisdiction

	Jurisdiction			
Functional System	Federal	State	Local	Total
Rural				
Interstate	0	33,378	0	33,378
Other Principal Arterial	132	80,691	128	80,951
Minor Arterial	1,522	144,692	1,113	147,327
Major Collector	4,180	208,806	223,198	436,184
Minor Collector	12,231	70,262	211,931	294,424
Local	160,124	168,677	1,801,659	2,130,460
Subtotal	178,189	706,506	2,238,029	3,122,724
Urban				
Interstate	0	11,471	0	11,471
Other Freeway & Expressway	59	7,192	331	7,582
Other Principal Arterial	94	35,393	16,002	51,489
Minor Arterial	65	19,788	54,893	74,746
Collector	48	8,028	70,398	78,474
Local	760	15,029	514,226	530,015
Subtotal	1,026	96,901	655,850	753,777
Total	179,215	803,407	2,893,879	3,876,501

Source: *Highway Statistics*, 1989.

vehicle miles-of-travel per year. About 60 percent of highway travel is in urban areas, with suburban portions growing most rapidly. Exhibit 2 shows average annual and five-year average rates of growth in total highway travel for selected years.

While travel grew rapidly in the 1980's, total highway mileage has changed very little. Mileage classified as rural has declined as urban mileage has increased. The reduction in the amount of rural mileage largely reflects reclassification from rural to urban status as a result of the growth in urban areas. It also reflects the transfer of certain roads in national forests to non-public status. Exhibits 3 and 4 summarize 1989 mileage and travel on functionally classified urban and rural highway systems.

Trends in Functional System Mileage and Travel

Travel increased on all functional systems between 1987 and 1989 by an annual rate of almost 4.7 percent. ***The slight increase in highway capacity, however, did not keep pace with the increase in travel demand, either in rural or urban areas.*** While travel nationwide increased by an average of over 4 percent per year between 1983 and 1989, available highway lane-miles increased only 0.1 percent per year. In urban areas, travel increased by 4.8 percent per year, and lane-miles increased by over 2.2 percent per year. In rural areas, travel

Exhibit 2
Highway Travel for Selected Years
1960 - 1990

Year	Total Highway Travel (millions)	Annual Change	5-Year Average
1960	718,762	2.61%	–
1965	887,812	4.91%	4.32%
1970	1,109,724	4.51%	4.56%
1975	1,327,664	3.68%	3.65%
1980	1,527,295	(0.12%)	2.84%
1981	1,552,803	1.67%	2.06%
1982	1,595,010	2.72%	1.69%
1983	1,652,788	3.62%	1.36%
1984	1,720,269	4.08%	2.38%
1985	1,774,179	3.13%	3.04%
1986	1,834,872	3.42%	3.39%
1987	1,921,204	4.71%	3.79%
1988	2,025,586	5.45%	4.16%
1989	2,107,040	4.00%	4.14%
1990 (est.)	2,165,000	2.75%	4.06%

increased by 3.25 percent per year, and lane-miles decreased by 0.4 percent per year.

Excluding local roads, the urban Interstate System experienced the largest increase in travel from 1983 through 1989, averaging almost 6 percent per year. Travel on both rural and urban collectors, at the other end of the spectrum, increased by less than 3.0 percent annually over the same period (Exhibit 5).

The density of urban highway travel, defined as vehicle travel compared to lane miles, is about four times the density of rural travel for similar functional

Exhibit 3
Rural Functional Classification Mileage and Travel, 1989

Functional Classification	Miles	Lane-Miles	Vehicle Miles of Travel (millions)
Prinicipal Arterials	114,329 3.7%	340,787 5.3%	357,113 42.1%
Interstate (included above)	(33,378) (1.1%)	(134,969) (2.1%)	(191,120) (22.5%)
Minor Arterials	147,327 4.7%	308,266 4.8%	156,626 18.5%
Collectors	730,608 23.4%	1,467,648 23.0%	235,267 27.7%
Local Roads	2,130,460 68.2%	4,260,920 66.8%	98,877 11.6%
System Totals	3,122,724	6,377,621	847,883

Exhibit 4
Urban Functional Classification Mileage and Travel, 1989

Functional Classification	Miles	Lane-Miles	Travel
Principal Arterial	70,542 9.4%	266,570 15.8%	719,604 57.2%
Interstate (included above)	(11,471) (1.5%)	(61,854) (3.7%)	(270,652) (21.5%)
Minor Arterials	74,746 9.9%	188,218 11.2%	234,863 18.7%
Collectors	78,474 10.4%	167,699 10.0%	101,259 8.0%
Local Roads	530,015 70.3%	1,060,030 63.0%	202,431 16.1%
System Totals	753,777	1,682,517	1,258,157

systems. The rate of increase in density of travel has been higher in rural areas than in urban areas in recent years but, in absolute terms, urban roads remain much more heavily used. In urban areas, travel on the higher functional systems, Interstates and other freeways and expressways, has continued to increase more rapidly than on other urban systems. The growth of rural travel demand has appeared most prominently on the margins of urban areas and in the corridors connecting urban areas. Conditions on these rural highways have begun to emulate urban highways, with reduced headway between vehicles, reduced speeds, and more stop-and-go conditions and delay during the peak demand hours each day.

Federal-Aid Systems Mileage and Travel

Of the approximately 1.2 million miles of roads functionally classified as either arterials or collectors, about 850,000 miles are also classified as part of one of the four administrative systems eligible for Federal-aid; the Interstate, primary, secondary, and urban systems. The Interstate System, which is functionally classified as a principal arterial system, is separately classified for administrative purposes.

Exhibit 5
Lane-Miles and Highway Travel Comparison

Functional System	Lane-Miles			Travel (millions of annual vehicle miles)		
	1983	1989	Annual Change 1983-89 (%)	1983	1989	Annual Change 1983-89 (%)
Rural						
Interstate	131,976	134,969	0.37	144,733	191,120	4.74
Other Principal Arterial	201,424	205,818	0.36	139,962	165,993	2.88
Minor Arterial	309,034	308,266	-0.04	133,421	156,626	2.71
Major Collector	867,549	880,650	0.25	136,786	187,182	3.00
Minor Collector	574,554	586,998	0.36	43,806	48,085	1.57
Local	4,442,784	4,260,920	-0.69	81,825	99,877	3.38
Subtotal	6,527,321	6,377,621	-0.39	700,533	848,883	3.25
Urban						
Interstate	53,386	61,854	2.48	191,149	270,652	5.97
Other Freeway & Expressway	30,817	33,739	1.52	86,790	122,055	5.85
Other Principal Arterial	150,892	170,977	2.10	255,327	326,897	4.20
Minor Arterial	172,395	188,218	1.47	188,467	234,863	3.74
Collector	153,118	167,699	1.53	86,593	101,259	2.64
Local	912,270	1,060,030	2.53	140,247	202,431	6.31
Subtotal	1,472,878	1,682,517	2.24	948,573	1,258,157	4.82
Total	8,000,199	8,060,138	0.12	1,649,106	2,107,040	4.17

Exhibit 6 shows the mileage and travel characteristics of the various Federal-aid systems. Federal-aid routes generally represent the most heavily travelled portions of the roads within the particular functional system from which they are drawn. These four systems collectively carry about 80 percent of highway travel on about 22 percent of total national mileage. The Interstate and primary systems, together, carried almost 50 percent of total highway travel in 1989.

Travel on Federal-aid systems increased annually by an average of 4.5 percent between 1987 and 1989. ***The increase in travel on a per lane-mile basis was over 14 times higher for Federal-aid as compared to non-Federal-aid highways in rural areas, and eight times higher in urban areas.***

The Bridge System

Nationwide, there are approximately 577,000 bridges of greater than 20 feet in length. Over 80 percent of these are in rural areas. Of the total, over 275,000 bridges, about 48 percent, are on a Federal-aid system. Of the remaining 300,000 plus bridges off the Federal-aid systems, about 225,000, or 75 percent, are on functionally classified local roads.

Highway Finance

Public Sector Highway and Bridge Financing

Revenues for highway finance comes from both the public and private sectors and are spent by various levels of government for both capital and noncapital purposes. In 1989, all levels of government provided $73.6 billion for highways programs, including capital and noncapital spending. The Federal Government funded $16.5 billion, the States $36.9 billion, and counties, cities and other local entities funded the remaining $20.2 billion. Federal funds, primarily supplied by

Exhibit 6
Federal-Aid Systems, Mileage and Travel Characteristics

Federal-Aid System	Miles	Lane-Miles	Travel
Interstate System	44,849 1.2%	196,823 2.4%	461,772 21.9%
Primary System	259,205 6.7%	624,871 7.7%	584,290 27.7%
Secondary System	399,756 10.3%	808,006 10.0%	179,300 8.5%
Urban System	147,904 3.8%	370,309 4.7%	463,341 21.9%
System Totals	851,714	2,000,009	1,688,703
% of National Total	22.0%	24.8%	80.1%

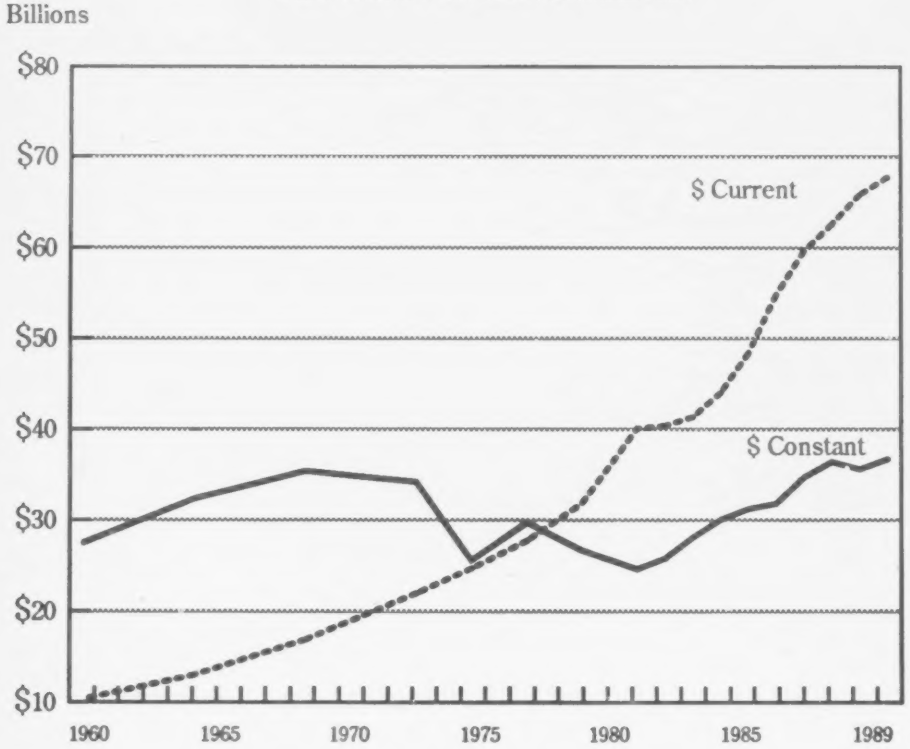
the Highway Trust Fund, accounted for 22.5 percent of the total funding for highways in 1989, down from 24.8 percent in 1980. The States accounted for one-half of all funding, a ratio unchanged over the last decade. Local governments have increased their share from 25.7 to 27.4 percent. After accounting for reserves and debt retirement, $67.7 billion was actually spent on highway and bridge programs.

Exhibit 7 shows expenditure trends in both constant and current dollars. Constant dollar spending on highways decreased from $27.5 billion in 1960 to $24.6 billion in 1980 before increasing to $36.7 billion in 1989. *In constant dollar investment per unit of travel, total expenditures have actually dropped by more than one-half since 1960.*

Public Sector Revenue Sources and Trends

Revenues for public sector highway programs come from a variety of sources including *user charges, nonuser benefit charges, investments and miscellaneous fees, bond issues, and nonhighway based revenue instruments*. Exhibit 8 indicates total public sector revenues by both source and level of government. User charges, including motor fuel taxes, motor vehicle taxes and tolls, accounted for 60 percent of revenues in 1989, up from 57 percent in 1980. General funds

Exhibit 7
Highway Expenditures by All Units of Government



and other nonhighway based revenue instruments are the next largest source of revenue, contributing about 16 percent of total spending, a 5 percent decrease since 1980. Benefit charges, including private cost sharing, where identified, provided 9 percent, the same as in 1980. Investment income and miscellaneous fees accounted for 8 percent in 1989, and bond issuances for the remaining 7 percent. All highway-based revenue sources, including user charges, benefit charges, investments and miscellaneous fees, and bond issues, provided approximately $62.16 billion or 84 percent of the revenues used for highways in 1989.

In constant dollars, total revenues from user charges increased from $22.8 billion in 1960 to $29.4 billion in 1989. Actual highway expenditures from this source grew from $22.0 billion in 1960 to $24.7 billion in 1989, indicating an increase in diversion of user revenues from 3.5 percent to 16 percent.

Highway Expenditures and Trends

Exhibit 9 illustrates disbursements for highways by functions for selected years. Noncapital highway expenditures include maintenance and operations of

Exhibit 8
Revenue Sources for Public Sector Financing of Highways – 1989 (billions of dollars)

	Federal	State	Local	Total	Percent
1. User Charges:					
Motor Fuel Taxes	11.92	17.03	0.54	29.49	40%
Motor Vehicle Taxes	2.20	9.32	0.32	11.84	16%
Tolls	–	2.50	0.51	3.01	4%
Subtotal	14.12	28.85	1.37	44.34	60%
2. General Funds and Other Non-Highway Based Revenue Instruments	0.99	1.52	8.95	11.46	16%
3. Benefit Charges:					
Property Taxes and Assessments	–	–	4.54	4.54	6%
Other Taxes and Fees	0.07	1.37	1.01	2.45	3%
Subtotal	0.07	1.37	5.55	6.99	9%
4. Investment Income and Miscellaneous Receipts	1.36	2.09	2.33	5.78	8%
5. Bond Issue Proceeds	–	3.06	2.00	5.06	7%
Total	16.54	36.89	20.20	73.63	100%

Source: *Highway Statistics, 1989*, Table HF-10 highways, administration, highway law enforcement, safety, and debt service on highway bonds and notes. Routine roadway maintenance takes the largest share of noncapital outlays and is not eligible for Federal-aid. The noncapital highway bill for the public sector was $38 billion in 1989, up from $21 billion in 1980. Noncapital spending as a share of total highway spending increased from 50 percent in 1980 to 53 percent in 1989.

Capital outlays consist of costs associated with right-of-way acquisition; planning and engineering; all forms of construction and reconstruction for capacity increase; rehabilitation and restoration (3R) on existing facilities; construction on new alignment; and installation of traffic service facilities. As shown in Exhibit 10, capital investment on nonlocal roads is almost evenly divided between physical and operational preservation versus capacity improvement.

All governments spent over $33 billion on capital outlays in 1989, up from $20 billion in 1980, a 65 percent increase. In constant dollars, the increase was 50 percent. The Federal Government provided 43 percent of the total highway capital outlays in 1989, an 11 percent decrease in share since 1980 (Exhibit 11).

Exhibit 9
Disbursements for Highways by Functions for Selected Years, All Units Of Government
(millions of dollars)

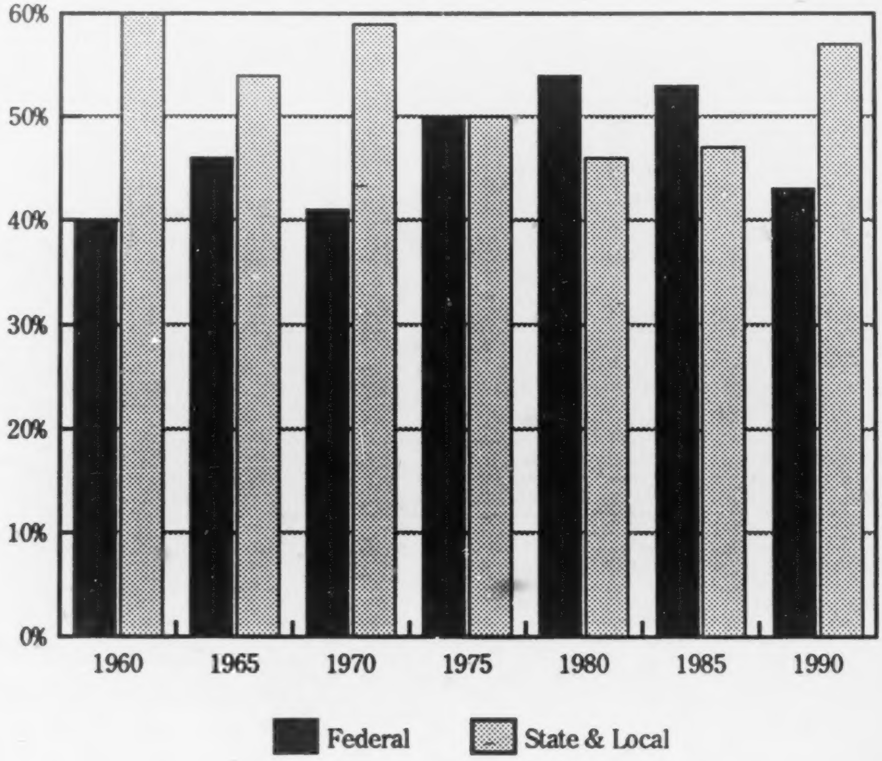
Year	Capital Outlay	Maintenance and Operations	Administration, etc.	Highway Patrol & Safety	Interest on Debt	Subtotal Current Disbursements	Debt Retirement	Total
1960	6,290	2,640	483	327	420	10,160	601	10,761
1964	8,252	3,060	684	474	515	12,985	752	13,737
1968	10,346	4,003	1,017	940	606	16,912	1,071	17,983
1972	12,275	5,443	1,600	1,671	950	21,939	1,270	23,209
1974	13,102	6,573	1,857	2,061	1,079	24,672	1,445	26,117
1976	13,927	7,735	2,209	2,633	1,234	27,738	1,567	29,305
1978	14,938	9,785	2,590	3,160	1,368	31,841	1,593	33,434
1980	20,337	11,445	3,022	3,824	1,456	40,084	1,711	41,795
1981	19,734	12,165	3,439	3,884	1,202	40,424	2,464	42,888
1982	19,052	13,319	3,152	4,068	1,690	41,281	2,046	43,327
1983	20,224	14,240	3,347	4,309	1,872	43,992	2,172	46,164
1984	23,123	15,008	3,604	4,937	1,641	48,313	2,411	50,724
1985	26,647	16,589	4,174	5,241	2,148	54,799	2,737	57,536
1986	29,179	17,643	4,677	5,549	2,505	59,553	2,793	62,346
1987	30,674	18,152	4,973	5,962	2,788	62,549	2,685	65,234
1988	32,883	19,110	4,961	6,108	2,773	65,835	2,755	68,590
1989	33,274	19,679	5,380	6,453	2,871	67,657	3,478	71,135

Source: *Highway Statistics*, HF-12, various years, and HF-10, October 1990.

Exhibit 10
Spending by Major Improvement Categories on Non-Local Roads

	Estimated 1989 Capital Expenditures (billions)	Percent
System Performance		
Pavement and safety improvements on arterials and collectors	$6.7	24%
Bridge replacement/rehabilitation on arterials and collectors	4.6	16%
Operational improvements to arterials and collectors	1.7	6%
Capacity Improvements		
Capacity additions to arterials and collectors	7.1	25%
New highway/bridge construction on arterials and collectors	7.8	28%
Total Capital Spending on Non-Local Roads	$27.9	100%

Exhibit 11
Highway Capital Outlay by Level of Government



Although real highway capital outlay per mile of travel increased slightly in the 1980's, it has decreased by about 60 percent since 1960 as illustrated in Exhibit 12.

Highway Capital Outlay on Federal-Aid Systems

Of the $33 billion spent on capital outlays by the public sector in 1989, $25 billion was spent on the Federal-aid systems. Federal-aid highway funds, which can be used only for capital improvements on a Federal-aid System, constituted approximately 56 percent of the capital investment on this system. State and local governments provided the remaining funds, an effective matching share rate of 44 percent. This was substantially beyond the 17 percent composite statutory match requirement for these systems, indicating that States also invest independently on the Federal-aid system, either by overmatching on projects receiving Federal-aid or by fully funding projects with their own revenues. Exhibit 13 summarizes this relationship between statutory and effective shares for the various Federal-aid systems.

Exhibit 12
Highway Capital Outlay
per 1,000 VMT

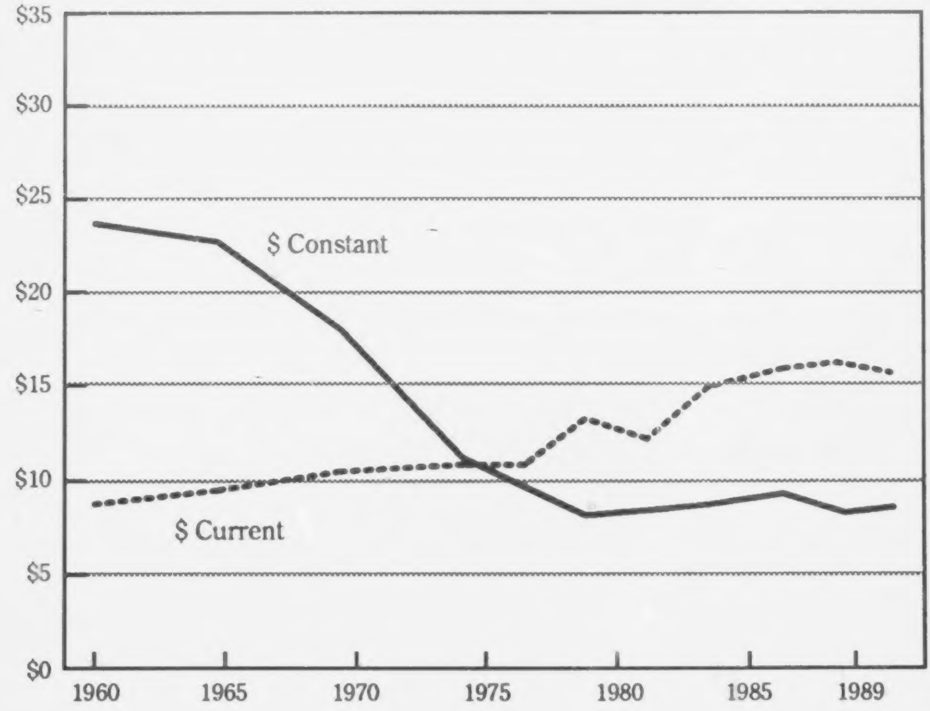


Exhibit 13
Statutory and Effective Federal Share of Investment on the Federal-Aid Systems, 1989

Federal-Aid System	Statutory Federal Share	Effective Federal Share
Interstate	90%	79%
Primary	75%	52%
Urban	75%	33%
Secondary	75%	29%

Spending for capacity improvements on the Federal-aid systems was 54 percent of total expenditures, similar to the spending pattern on all nonlocal roads.

Preliminary Estimates of Private Financing

It is well known that the private sector is involved in financing roads. Private investors typically finance development-related (commercial or residential) "on-site" roads as part of the land development process. It is estimated that the value of such local roads put in place by private contributions in 1989 exceeded $6 billion.

There is an increasing trend of public-private cost-sharing for "off-site" collector and arterial improvements as well, through innovative financing mechanisms such as impact fees, benefit assessment districts, right-of-way, and cash donations. Since private finance is only partially captured in current highway finance data, a preliminary small sample analysis undertaken indicates that private investments in arterials and collectors during 1989 may range from $2 to $5 billion. It is estimated that about one-third of this range is already accounted for in the annual *Highway Statistics* report, the basis for the discussion of highway finance earlier in this summary.

The preliminary nature of these estimates notwithstanding, the "on-site" and "off-site" estimates indicate an additional $8 to $11 billion for capital investment in highways which, if included in totals, would yield a possible national capital investment estimate in excess of $40 billion in 1989.

Highway Conditions, Performance and Safety

Physical Conditions

Highway physical condition is reflected in pavement condition, lane width, horizontal and vertical alignment, drainage adequacy, and other measures that relate to the road's physical integrity or level of safety. With the exception of pavement, these measures tend to improve over time as capital investment brings the design of the roadway up to modern safe design standards. However, pavement conditions can degrade because of normal use and weathering, increases in traffic or vehicle sizes and weights, and current and past levels of maintenance and capital spending.

Current pavement conditions, along with the expected future demand for travel by the various classes of vehicles, are prime determinants of capital investment requirements. Pavements are rated in terms of a present serviceability rating (PSR), a composite rating of overall pavement quality. The rating is made according to the amount of distress evident; that is, cracking, spalling, rutting, and a variety of other features that indicate various stages of physical deterioration, ride discomfort, and cost of repair. Pavements rated as "poor" or "low fair" typically require vehicles to travel more slowly than the posted speed limit, with more acceleration and deceleration to avoid bad pavement. This reduces fuel efficiency, wears out brakes and shock absorbers more quickly, and might lead to more frequent front end alignments.

PSR is rated from 5.0 to 0.0, with the higher number representing perfect pavement and the lower number completely deteriorated pavement. Ratings less than or equal to 2.0 are considered "poor" for most roads, although the Interstate System, which is expected to perform at a higher design level, is rated as "poor" at PSR equal to 2.5 or less. "Low fair" is an indication of the amount of pavement that is approaching poor and must be addressed in the near future by some type of capital investment.

Although pavement conditions and trends vary significantly among the States, average conditions on the Nation's arterial and collector systems appear to have stabilized in 1989, stemming a continuous downward trend in physical conditions that was evident in the 1970's and early 1980's.

The overall stabilization can be attributed to several factors, including: (1) passage of the Surface Transportation Assistance Act of 1982, with the 5-cent increase in Federal gas tax and programmatic incentives for pavement rehabilitation; (2) continued State efforts to allocate additional funds for highway capital investment; and (3) the development and use of systematic pavement management systems to identify deficiencies and allocate resources in a cost-effective manner. As a result, future investment levels for pavement improvements necessary to sustain these accomplishments should be lower, assuming that investments are made on a continuing and sufficient basis.

Still, about 265,000 miles were rated in poor condition in 1989 and an additional 377,000 miles were rated in "low fair" condition (Exhibit 14). *Pavements in "poor" condition typically require reconstruction to restore serviceability. Reconstruction involves the removal and replacement of paving material down to, and possibly including, the subbase. Pavements rated as "low fair" are at a point at which pavement management programs can prolong the life of the highway surface with lower cost 3R types of pavement improvements. 3R improvements, which consist of resurfacing, restoration, and rehabilitation, typically involve lower capital intensity of work to restore serviceability. The unit cost of reconstruction*

varies between 150 and 250 percent of the cost of resurfacing. If preemptive investments are not made in an orderly fashion, however, pavements will seriously deteriorate. The cost of eventual repairs using reconstruction techniques will be much higher, and highway users will pay more in vehicle repair and fuel consumption costs until the repairs are made.

The combination of "poor" and "low fair," or about 642,000 miles, means that in 1989 almost half of all arterial and collector mileage was at or near the point at which vehicle operating characteristics (and user costs) are significantly impaired by deteriorated conditions. Even with the stabilization of the deteriorating trend in pavement conditions, the magnitude of pavements that remain in poor or low fair condition, combined with the continuing deterioration of other pavements currently in high fair or good condition, mean that each year about 100,000 miles of arterials and collectors must have some type of pavement improvement to restore their serviceability.

Performance Characteristics

While physical conditions stabilized, system performance deteriorated, especially on the Nation's higher level highway systems (Exhibit 15). *By all system performance measures of highway congestion and delay, performance is declining. Congestion now affects more areas, more often, for longer periods, and with more impacts on highway users and the economy than at any time in the Nation's history.*

Exhibit 14
Pavement Conditions, 1989

	Poor (1)	Low Fair (2)	High Fair	Good	Total
Interstate					
Miles	4,150	7,010	7,597	26,092	44,849
(% system)	(9.3)	(15.6)	(16.9)	(58.2)	(100)
Other Arterials					
Miles (3)	21,802	114,549	60,288	165,456	362,095
(% system)	(6.0)	(31.6)	(16.6)	(45.7)	(100)
Collectors					
Miles (4)	239,631	255,549	80,329	233,572	809,081
(% system)	(29.6)	(31.6)	(9.9)	(28.9)	(100)
Totals					
Miles	265,583	377,108	148,214	425,120	1,216,025
(% system)	(21.8)	(31.0)	(12.2)	(35.0)	(100)

(1) Poor is defined for all roads as present serviceability rating (PSR) less than or equal to 2.0, 2.5 for the Interstate.
(2) Low Fair is less than or equal to 2.5, 3.0 for the Interstate system.
(3) Other Arterial mileage includes 504 unpaved miles (rated poor).
(4) Collector mileage includes 149,570 unpaved miles (rated poor).

Congestion has three attributes: **severity**, **duration**, and **extent**.

- **Severity:** Almost 70 percent of daily peak-hour travel on the urban Interstate System in 1989 occurred under congested or highly congested (near stop-and-go) conditions. This represents an increase of almost 30 percent since 1983. About 43 percent of travel on other urban arterials also experienced congested conditions, an increase of over 18 percent since 1983. The percentage increase in congested rural Interstate travel was even greater than on urban Interstate routes, although the affected volume was less.

- **Duration:** Based on a sample of urbanized areas of different sizes, the duration of daily freeway travel operating at extremely congested conditions, approaching a complete breakdown, or gridlock, increased 45 percent from 1985 to 1988, from 5.4 to 6.2 percent of daily vehicle miles of freeway travel. This was twice the rate of travel increase. Daily travel that faced heavy congestion increased almost five times as fast as the increase in added lane-miles of freeway capacity over the same period for these urbanized areas.

- **Extent:** The proportion of total travel under congested conditions is highest in the largest urbanized areas. An estimated 50 to 60 percent of all urban travel delay occurs in the 10 largest urbanized areas. However, congestion is extending to more areas, especially to suburban areas and to facilities that connect and approach urban areas. The greatest increase in congestion among HPMS Interstate and other freeway samples has been to those that form the approaches and connections between major urbanized areas. Although congestion is often viewed as a commuter phenomenon, its effects in major cities have not been limited to the peak-periods. Off-peak congestion is becoming more widespread and pervasive.

Exhibit 15
System Performance

System	Congested (1)	Highly Congested (2)	Total Congested
Urban Interstate	18.4%	51.2%	69.6%
Other Urban Arterials	14.1%	29.2%	43.3%
Urban Collector	8.4%	11.0%	19.4%

(1) Congested: V/C = 0.8 to 0.95

(2) Highly Congested: V/C > 0.95

NOTE: A volume to capacity ratio (V/C) of 0.8 means that traffic volume has reached 80 percent of the capacity of the facility. Congestion begins to occur at about that point. A V/C ratio of 0.95 means that traffic has almost reached the saturation point of the facility, at which point "gridlock" (V/C of 1.0) occurs.

Using HPMS data, the Texas Transportation Institute estimated the costs of highway congestion in 39 of the Nation's largest cities to be approximately $34 billion. Eighteen of the 39 areas studied had congestion indices that placed them in the "undesirable" category and, of those 18 only five showed congestion improvements from the previous year. Congestion was defined as delay caused by levels of service at "D" or above and the costs of delay included drivers' time and increased fuel consumption.

Bridge Conditions

Deficient bridges are categorized as either structurally deficient or functionally obsolete (Exhibit 16). Structural deficiency does not necessarily mean that a bridge is unsafe. It means that the bridge is unable to handle the vehicle loads or speeds that would normally be expected on the highway system where the bridge is located and is posted to indicate such limitations.

Functional obsolescence means that the bridge has inadequate width or vertical clearance for its associated highway system. In some cases, bridges are made functionally obsolete because of highway improvements on the approaches to the bridge; for example, lane additions or widening of approaching roads. In other cases, a bridge may be reevaluated as functionally obsolete through a redefinition of desired standards.

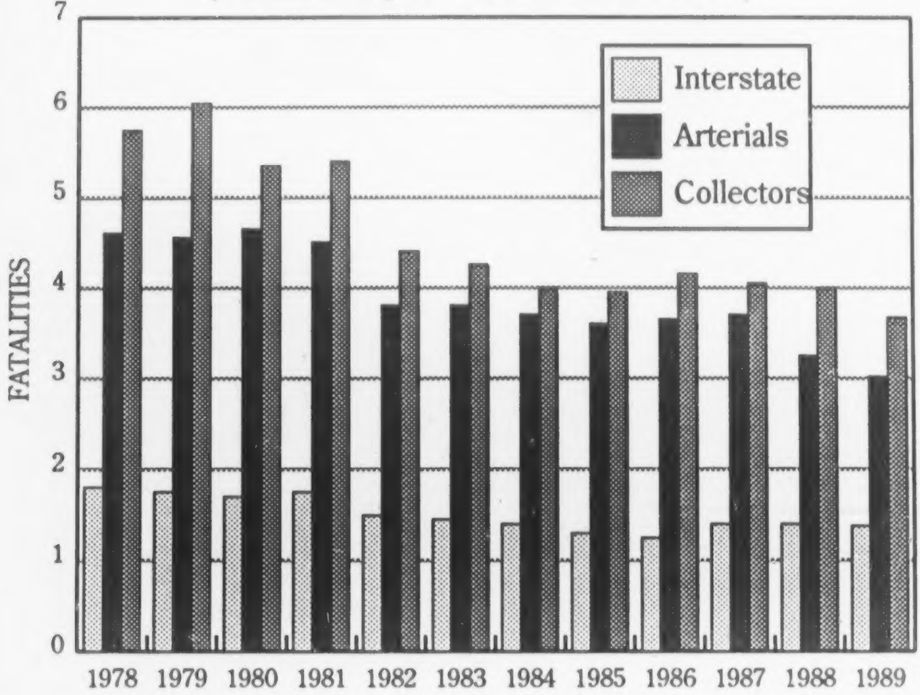
Of the more than 340,000 bridges on arterial and collector roads, about 112,000 were considered deficient as of June 30, 1990. Of these, about 15,000 were on the Interstate System, about 40,000 were on other arterial highways, and almost 57,000 were on collector roads. This is an increase of 1.5 percent in the total number of deficient bridges since 1984.

Since 1984, the number of structurally deficient bridges on arterials and collectors has increased by 25 percent. Between 1988 and 1990, the number of structurally deficient bridges decreased on the Interstate and other arterials but, because of an increase in structural deficiencies on collector bridges, there was an overall increase of about 1.5 percent. The number of bridges rated as functionally obsolete increased on the Interstate and other arterial highways

Exhibit 16
Bridge Deficiencies, 1990

Functional System	Structurally Deficient	Functionally Obsolete	Total Deficiencies	Total Bridge on the System
Interstate	3,848	11,360	15,208	53,183
Other Arterial	15,989	23,502	39,491	124,615
Collector	33,056	23,566	56,622	164,300
Local	81,179	33,326	114,505	234,567
Total	134,072	91,754	225,826	576,665

Exhibit 17
Rural Highway Fatality Rates
(Fatalities per 100 million VMT)



Source: Fatal Accident Reporting System Annual Reports, 1978 – 1988

and decreased on collectors between 1988 and 1990 because of the redefinition of certain types of deficiencies[2].

Highway Safety

Steady long term improvements have been made in highway safety throughout the 1980's on all highway systems (Exhibits 17 and 18). Overall, the national highway fatality rate has declined to 2.16 fatalities per 100 million vehicle miles-of-travel in 1989, down from 3.3 in 1980. The Interstate System, with its full access control, traffic separation, wide lanes, full shoulders, and other high design standards, was by far the safest highway system, with 1.1 fatalities per 100 million vehicle miles-of-travel.

Fatality rates were lower on urban roads than on rural roads. Rural collectors, with their higher incidence of deficient geometry, absence of shoulders or vehicle recovery areas, and generally poorer emergency response time, exhibited the highest fatality rates, at 3.68 per 100 million vehicle miles-of-travel.

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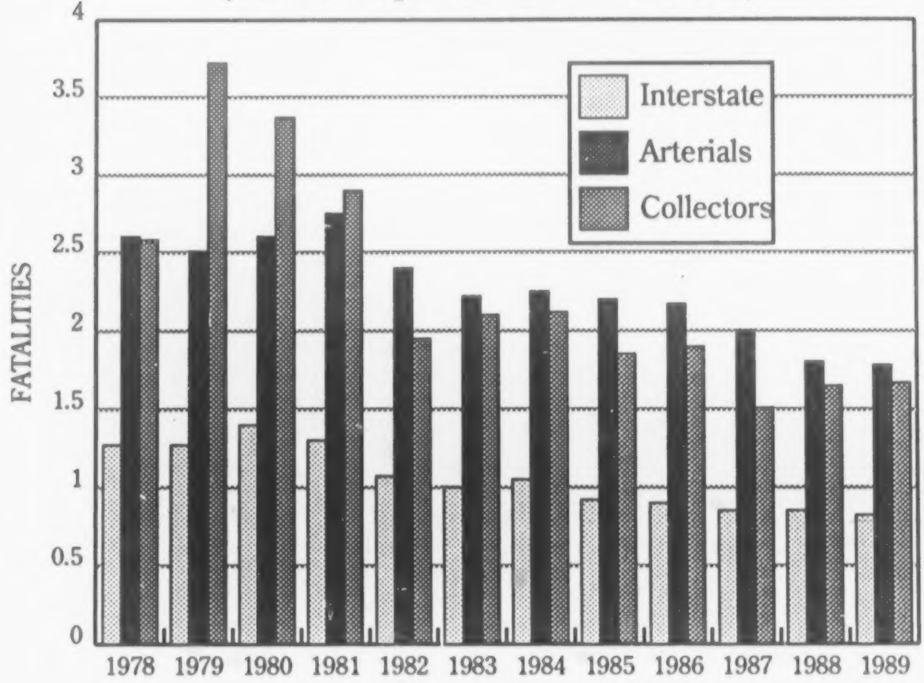
2 *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, FHWA. December 1988

Exhibit 18
Urban Highway Fatality Rates
(Fatalities per 100 million VMT)



Source: Fatal Accident Reporting System Annual Reports, 1978 – 1988

Highway and Bridge Investment Requirements, 1990 to 2009

This report provides estimates for total capital investments required to achieve certain specified levels of overall system condition and performance for all highways and bridges for the period 1990 to 2009. These include costs: (1) to repair deficient pavements and bridges; (2) to eliminate unsafe conditions; and (3) to add the capacity necessary to achieve specified levels of system performance.

Investment requirements are presented in terms of two scenarios:

- the costs to *improve* the conditions and performance on all nonlocal roads and bridges that either are, or are expected to become, deficient through 2009, to a specific minimum engineering standard associated with moderate performance, and

- the costs to ***maintain*** current overall conditions and performance on most nonlocal roads (1989) and bridges (1990) through 2009, within the context of anticipated highway travel growth.

Analytical models provide estimates of the cost of meeting engineering standards specified for physical conditions and performance level of service in each scenario. The assessment procedures treat individual elements of highway systems and bridges as discrete elements of infrastructure that provide service and, in turn, require maintenance and repair to ensure their serviceability and physical integrity. Condition and performance deficiencies are treated independently and all facility functional classes, administrative jurisdictions, urban or rural locations, receive equal consideration over the entire public road system.

No policy priorities regarding strategic importance of individual facilities or classes of highway are assumed in determining scenario costs, nor are institutional constraints to highway and bridge improvements, such as fiscal capacity or air quality considerations in non-attainment areas. Certain policy-oriented assumptions have been made, however, such as reduced rates of travel growth in highly congested urban areas, the application of rigorous supply and demand management strategies prior to estimation of construction costs, and a constraint on the amount of new highway capacity in large urban areas.

The scenarios are not intended to represent comprehensive alternative national investment policies. They provide general financial and performance benchmarks and a basis for development and evaluation of policy and program options.

Highway and Bridge Investment Analysis Procedures

The highway estimates were developed using the HPMS Analytical Process. Bridge estimates were developed using the Bridge Needs and Investment Process (BNIP). Both of these are engineering-based investment simulation models in which the need for investments are indicated when current or simulated future pavement, structural, geometric, safety or service-related conditions deteriorate below a set of prescribed minimum condition standards.

The minimum condition standards, improvement strategies, types and costs of improvements simulated vary according to the system on which the facility is located, and follow accepted engineering practices. The concept of life-cycle costs, defined as the total capital and maintenance costs required over the life of an improvement, is built into the simulation procedure. Design standards applied and improvement strategies simulated are selected to produce a cost-effective and safe highway and bridge system. Pavement improvements simulated reflect the demands of traffic loadings five to seven years into the future; capacity additions reflect travel growth 20 years into the future.

Highway Travel Demand Growth Assumptions

Future highway travel demand is a key determinant of investment requirements. The rate of growth in highway travel has exceeded 3.0 percent for most 5-year periods since 1960, with the exception of the years of the OPEC cartel in the 1970's and the recession of 1980 to 1982, which affected the five-year rate through 1984. Over the period of 1983 through 1989, travel increased at an average annual rate of 4.2 percent, although preliminary estimates for 1990 indicate only a 2.75 percent increase in highway travel over 1989, attributable to reduced economic growth.

This report assumes that the average rate of growth in highway travel will decline gradually beyond 1990 to a level of slightly above one percent by 2009, to achieve an average over the period of about 2.5 percent per year through 2009 (Exhibit 19). This rate implies an increase in annual vehicle miles of travel of 65 percent compared to 1989.

Rates are expected to vary by State, ranging from about 0.5 percent to 5.3 percent growth per year with a distribution similar to that reported in the 1989 Report to Congress. Rates are also expected to vary between rural and urban areas, and by size of urban area. Growth in the top ten urbanized areas is expected to be substantially lower than all other urbanized areas, ranging from 0.6 percent to 1.8 percent annually.

Although these overall growth rates may seem low when compared to historic rates, several factors contribute. Demographic changes, especially the increasing number of older Americans, who tend to drive fewer miles than the population as a whole, and the "saturation effect" in the driver licensing rates of male drivers and number of vehicles on the road will be important moderating influences. (Saturation means that virtually all people of driving age have driver's licenses and access to personal vehicles.) Countering these influences, but not expected to outweigh their effects, will be a continuing growth of licensing and travel rates by female drivers, as well as increasing truck travel.

For purposes of sensitivity analysis, investment estimates have also been developed for an average annual growth rate of 3.0 percent.

Exhibit 19
Estimated Travel Growth Rates 1990-2009

	Forecast * Travel Growth Rates 1990-2009	**Simulated** * Travel Growth Rates 1990-2009
Rural Areas	2.58%	2.58%
Small Urban Areas	2.49%	2.49%
All Urbanized Areas	2.45%	1.42% – 1.46%
Top 10 Urbanized Areas	1.99%	1.21%
Total	2.51%	

* The forecast growth rates are those coded in the 1989 HPMS database. The simulated rate for which capacity costs are determined assume peak spreading and a 12-lane restriction on facilities in urbanized areas.

Peak Spreading and Congestion Management

The future highway demand for which capacity-related investment requirements in urban areas have been estimated has incorporated corridor constraints; first, through peak spreading; and, second, through imposition of an upper limit of 12 lanes per corridor (not facility) basis, recognizing right-of-way and cost constraints.

Travel demand has been further factored downward to reflect the widespread application of "congestion management" in urban areas as a cost-effective component of capacity enhancement — prior to the calculation of new construction-based capacity improvements. The simulation process estimates the potential reduction in new highway capacity demand that could be expected as a result of a systematic nationwide application of "supply management" — an aggressive application of comprehensive traffic and freeway operational elements, and a parallel "demand management" program assuming parking management, ridesharing, and transit strategies. These programs are applied uniformly with effectiveness assumed to be equivalent to or better than the best demonstrated experience to date.

The simulation represents these efficiency and reduced demand assumptions as reduced lane-miles of new capacity required to achieve the system performance goals established by the scenario. The combined changes, including the congestion management strategy, the restriction on capacity additions, and the peak spreading, reduce the total travel demand to be accommodated through capacity improvements by between 56,000 and 83,000 urban lane-miles of capacity. Between 30,000 and 45,000 of these are in the top ten urbanized areas. These lane-miles and capacity costs are not included in the cost analysis. In Exhibit 19, total travel demand is shown under the Forecast column. The Effective column indicates the amount of travel for which capacity costs have been simulated; that is, the reduction in travel expected from the congestion management, capacity restriction, and peak spreading strategies.

The combined assumptions of these constraints and congestion management efforts produce estimates indicating urban highway systems that, on average, will be able to function at today's levels of service with only an 18 percent increase in lane-miles of capacity over the next 20 years, while accommodating a 65 percent increase in demand.

In the ten largest urbanized areas, this results in an increase in demand averaging only 1.2 percent annually, reflecting physical and environmental limitations such as those that might be imposed by air quality considerations. As a result, the capacity increases simulated are considerably less, totalling approximately 8 percent from 1990 through 2009.

Expanded Investment Requirements Coverage

Following submittal of the 1989 report, the Congress requested that a "broad array" of investment options be considered in future reports to parallel actual spending patterns more completely, including the costs of both preserving and improving existing conditions and performance. This report incorporates the range of investment strategies at both higher and lower capital intensity typical of most States. Exhibit 20 summarizes the types of highway and bridge improvements addressed in most highway investment programs and indicates which of these have been included in this report compared with previous versions:

- **Capacity additions within larger urbanized areas** requiring higher cost right-of-way expansion, grade-separation or new lanes in parallel corridors — up to a 12 lane total on a corridor-wide basis. Travel demand that would require capacity additions beyond this limit is reported as "unmet lane-miles of demand" and is not included in the investment requirements estimates. (The amount of new capacity not included due to this restriction is equal to 37 percent of the total new capacity that is included to maintain or improve levels of service to meet expected travel demand).

- **Highway and bridge infrastructure in expanding suburban areas,** which have been, and are expected to continue, as the locus of major highway travel demand increases. An estimate is included for new highway capacity re~~quired to~~ preserve or improve level of service in "areas classified as rural but expected to be urban in character by the year 2009."

- **Local roads** — An estimate of future capital requirements for the approximately 2.6 million miles of local roads has been included, based on a 1987 survey conducted by the U.S. Department of Agriculture on the

Exhibit 20
Program And Report Coverage

Highway and Bridge Improvements Addressed by State and Local Highway Agencies	1989 Report	1991 Report	Estimated 1989 Capital Expenditures (billions)
Pavement and safety improvements to arterials and collectors	Yes	Yes	$6.7
Capacity additions to existing arterials and collectors	Some	Yes	$7.1
New arterial and collector highway and bridge construction	No	Limited	$7.8
Capital improvements to local functional class, including new construction	No	Yes	$5.4
Bridge replacement and rehabilitation on arterials and collectors	Yes	Yes	$4.6
Defense highway and bridge requirements	No	Yes	included in other categories
Operational improvements	No	Yes	$1.7
Total			$33.3

physical conditions of local roads and an assessment of current capital costs incurred by municipal and county governments.

- **Defense highway requirements** — Approximately 60,000 miles of Interstate and other arterial highways comprise the Strategic Highway Defense Network, or STRAHNET. For purposes of military mobilization, these highways have higher design specifications in order to accommodate large and heavy military vehicles.

Exhibit 20 compares the estimated 1989 capital expenditures by all units of government for all types of improvements with the expanded coverage supplied in this report, indicating the significance of this increased comprehensiveness. While earlier reports reflected about two-thirds of total spending requirements, this report covers an estimated 85 to 90 percent of requirements. Private investment, possibly accounting for $8 to $11 billion, is not included in this table.

The new investment requirements — both high and low capital intensity — are included in the summary of total investment requirements (Exhibit 29).

Highway Investment Requirements, 1990 to 2009

This report provides estimates of investment requirements determined by two condition and performance "benchmarks":

- The *Improve Overall Conditions and Performance* scenario provides an estimate of the costs associated with achieving and maintaining predefined condition standards for physical conditions and performance on all arterial and collector highways that are either currently deficient, or are expected to become deficient at some point during the 1990 – 2009 analysis period. These standards reflect high levels of roadway safety through the elimination of unsafe highway curves and grades and narrow lane widths, efficient life-cycle costs for physical preservation through a sustained cost-effective level of pavement condition, and more productive peak-period service levels, just above stop-and-go conditions.

This scenario would improve conditions and performance across all functional systems on a uniform basis nationwide, urban and rural, even as travel demand increases, except in the largest urbanized areas, where performance cannot be significantly improved because of the assumed capacity restrictions. The scenario represents a ***significant*** improvement in condition and performance on the majority of highways since the complete backlog of deficiencies would be eliminated.

This scenario establishes no particular priorities regarding cost-effectiveness and is not intended to represent an optimum recommended investment strategy. For example, it includes pavement improvements on lower volume roads and substantial urban capacity additions in high cost areas, improvements exhibiting a range of cost-effectiveness that might never be made because of siting problems, constrained highway budgets, or environmental and air quality concerns. However, the scenario provides a consistent frame of reference for policy development by establishing a measure of the total capital costs of providing a desirable level of highway and bridge infrastructure on all facilities, using good engineering practices, in response to a future travel demand growth averaging 2.5 percent annually.

- The *Maintain Current Overall Conditions and Performance* scenario provides an estimate of the cost of maintaining both current overall physical conditions and current levels of performance as traffic increases over the 20-year analysis period. While current physical conditions vary widely as shown in Exhibit 14, average conditions are rated as "fair," with about half of the Nation's arterial and collector pavements rated in "good" or "high fair" condition and the other half in "poor" or "low fair" condition. Current levels of performance include about 70 percent of urban Interstate peak-period travel and 43 percent of other urban arterial peak-period travel occurring under congested or highly congested conditions. As with the "Improve" scenario, overall system performance would not be maintained in the largest urbanized areas, assuming the amount of travel increase expected, even with an aggressive traffic management program. However, under the funding levels associated with this scenario, States could improve conditions of the higher priority routes.

Together, the two scenarios, by simulating the costs associated with both today's conditions and a uniformly applied set of condition and performance minimum standards, provide benchmarks against which to consider current investment strategies and policies. While the scenarios invest on a rigorous systemwide basis without application of policy-based priorities or fiscal constraints, they provide the basis for examining investment implications on a functional class basis, for urban versus rural comparisons, and for determining the cost implications of various combinations of conditions and performance.

The Backlog of Arterial and Collector Highway Deficiencies

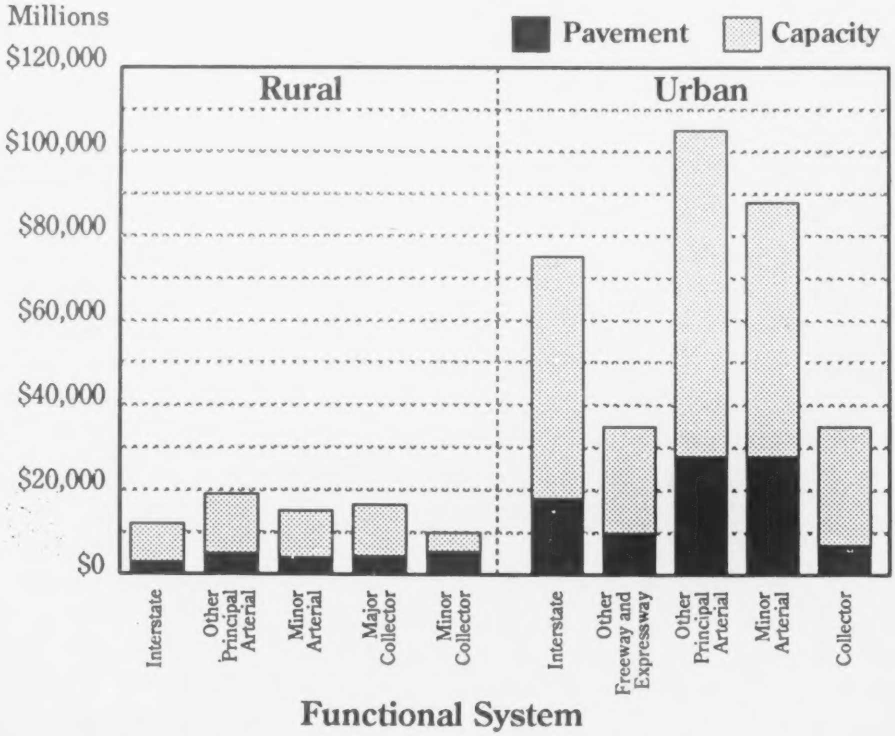
Investment requirements can be related to both *backlog* and *accruing* deficiencies. The backlog is the cost of bringing the current system up to at least minimum standards from its existing conditions and performance status. An accruing requirement refers to the cost of repairing deficiencies that will occur in the future as the result of travel demand and system deterioration attributable to traffic loads and normal weathering.

The backlog of needed improvements has increased since the last report because of deterioration in overall average system condition and performance. The deterioration also means that the nature of improvements to remedy backlog deficiencies has changed. ***As of December 31, 1989, the cost of eliminating the backlog of highway deficiencies was estimated at $400 billion for all existing arterials and collectors. The cost of deferring improvements on roads that were identified as deficient in 1987 and remained deficient in 1989 added $8 to $12 billion to the backlog estimate in 1989.*** This difference in cost is the additional cost of *reconstructing* roads now that were previously identified in 1989 as needing *resurfacing* or some other type of lower cost pavement improvement. Exhibit 21 presents total backlog deficiency costs.

About 28 percent of the backlog estimate is pavement cost; the remaining 72 percent is the cost of adding capacity to restore system performance to or above the level of service defined by the minimum condition standards. Backlog requirements in urban areas are significantly higher than those in rural areas, mostly due to inadequate highway capacity. Backlog deficiencies are fairly evenly distributed among the functional highway systems. Higher order systems have higher amounts of capacity backlog deficiencies, while lower order systems, both urban and rural, tend to have relatively higher amounts of safety and pavement related backlog deficiencies.

Each of the two investment scenarios treats backlog deficiencies differently. **The Improve Conditions** scenario includes investments to eliminate backlog as well as to respond to accruing deficiencies. The **Maintain Conditions** scenario does not eliminate the backlog as a goal, but makes investments selectively on both backlog and accruing deficiencies such that *overall* conditions and performance remain essentially unchanged. As a result, the overall backlog continues to exist.

Exhibit 21
1989 Backlog Needs



The "Improve Conditions and Performance" Scenario

The average annual investment required from all sources of funding for repairing all backlog deficiencies and keeping arterials and collectors above the specified minimum condition and performance level standards through 2009, ranges from $60.4 to $68.4 billion, depending on the number of years taken to repair backlog deficiencies. This estimate includes the capital savings of an aggressive congestion management program, estimated to reduce construction costs by about $3.4 billion annually.

This scenario would require an average investment of about 3.2 cents per 1989 vehicle mile of travel, compared to about 1.2 cents, or approximately $22 billion, invested in 1989 for corresponding capital improvements on the same highways.

Exhibit 22 presents *Improve Conditions and Performance* investment requirements for the period 1990 to 2009. The exhibit shows total 20-year investment requirements categorized as pavement and capacity improvements, with annualized totals. The annualized total is the 20-year total divided equally.

Under this scenario, approximately two-thirds of total investment would occur in urban areas. Capacity improvements would account for over 70 percent of urban investment, and over 60 percent of total investment. Approximately 30

Exhibit 22
Improve 1989 Conditions and Performance Scenario
2.5% VMT Growth Rate
(billions of 1989 dollars)

Improvement Type	Capacity	Pavement	Total
Rural			
Interstate	38.8	26.1	64.9
Other Principal Arterial	45.2	28.9	74.1
Minor Arterial	31.2	43.1	74.3
Major Collector	30.6	77.4	108.0
Minor Collector	15.2	45.0	60.2
Subtotal	161.0	220.5	381.5
Urban			
Interstate	169.0	45.2	214.2
Other Freeway & Expressway	68.2	16.8	85.0
Other Principal Arterial	176.8	60.3	237.1
Minor Arterial	127.6	56.5	184.1
Collector	56.6	49.0	105.6
Subtotal	598.2	227.8	826.0
Total	759.2	448.3	1,207.5
Annual	38.0	22.4	60.4

percent of total investment would be the cost of eliminating the backlog of deficiencies.

Exhibit 23 shows the current and future number of lane-miles of highway facility by functional class in both rural and urban areas under this investment scenario. The 2009 values are shown in two columns: (1) lane-mile requirements for capacity expansion and (2) lane-mile requirements for new right-of-way/higher cost capacity. No facility is simulated to have more than a total of 12 lanes of existing plus new capacity combined.

System Conditions and Performance Impacts Implementation of the *Improve Conditions and Performance* scenario would result in modest improvements in overall pavement conditions on the higher functional systems. This is because between 85 and 90 percent of these pavements already meet the minimum standards of 2.0 pavement serviceability rating (PSR), or 2.5 PSR for the Interstate System. This scenario would *significantly* improve conditions on minor arterials and collectors, where the backlog of condition problems is higher.

Exhibit 23
Total Lane-Mile Requirements – Improve Conditions (2.5% Annual VMT Growth Rate)

Functional System	1989	2009 Lane-Miles Required		
		Expansion Capacity	New ROW Higher Cost Capacity	Total
Rural				
Interstate	134,969	184,442	4,987	189,429
Other Principal Arterial – High	74,095	140,626	9,575	150,201
Other Principal Arterial – Low	131,723	87,333	443	87,776
Minor Arterial	308,266	327,089	7,562	334,651
Major Collector	880,650	892,352	4,739	897,091
Minor Collector	586,998	589,558	300	589,858
Subtotal	2,116,701	2,221,400	27,606	2,249,006
Urban				
Interstate	61,854	81,718	11,522	93,240
Other Freeway & Expressway	33,739	43,790	6,208	49,998
Other Principal	170,977	210,283	35,710	245,993
Minor Arterial	188,218	226,132	31,176	257,308
Collector	167,699	186,744	15,635	202,379
Subtotal	622,487	748,667	100,251	848,918
Total	2,739,188	2,970,067	127,857	3,097,924

Note: In rural areas, high OPA's have AADT of greater than 6,000. Low OPA's have AADT less than or equal to 6,000.

As shown in Exhibit 24, this scenario would also *significantly* improve system performance on many urban and some rural highways, supporting at least the minimum performance standard level of service E during the daily peak-period of demand. At, and just beyond this performance level, congestion begins to seriously impede traffic flow, with intermittent stop-and-go conditions, increased delay, fuel consumption, vehicle operating cost, and vehicle emissions.

Implementation of the *Improve Conditions and Performance* scenario would not only eliminate most highly congested conditions, it would also improve performance on high volume highways soon to be congested given the projected traffic growth rate. In effect, this investment scenario builds a "reserve" of capacity to accommodate future travel at the minimum conditions standard levels of service over a 20-year period.

The scenario does not imply system perfection. Conditions and performance would be superior to today, but pavements would not be "like new" nor traffic free flowing. The amount of congestion would be reduced by nearly one-half compared to today but the 12-lane capacity limitation described earlier means that several larger metropolitan areas would have high levels of "latent demand," travel demand that is desired, but for which insufficient capacity is available. No section of road would be in "poor" physical condition, as defined by the minimum condition standards used to identify deficiencies, but large segments of the highway system would be left with physical characteristics that are indicative of a system in fair condition.

Exhibit 24
System Performance Impacts of the Improve Conditions and Performance Strategy

System	1989		2009	
	Capacity (V/C > 0.8)	Pavement (Poor)	Capacity (V/C > 0.8)	Pavement (Poor)
Rural				
Interstate	23%	9%	15%	0%
Other Principal Arterial	9%	5%	5%	0%
Minor Arterial	6%	5%	1%	0%
Major Collector	4%	10%	0%	0%
Minor Collector	1%	12%	0%	0%
Urban				
Interstate	70%	10%	45%	0%
Other Freeway & Expressway	60%	3%	35%	0%
Other Principal Arterial	43%	6%	25%	0%
Minor Arterial	34%	9%	20%	0%
Collector	21%	18%	10%	0%

Unmet Demand. The *Improve Conditions and Performance* scenario would leave about 49,000 lane-miles of unmet demand in future years, because of the 12-lane constraint assumed for the analysis. About 50 percent of this unmet demand would be concentrated in the Nation's ten largest urbanized areas. The remaining 50 percent would be distributed throughout the Nation, primarily in urbanized areas of at least 500,000 population. Because of this assumed constraint on the addition of capacity, regardless of its warrant, *performance in these larger urbanized areas can be expected to deteriorate in future years, even with the aggressive congestion management strategy assumed in this scenario.*

The "Maintain Current Condition and Performance" Scenario

The average annual cost to maintain overall 1989 conditions and performance on existing arterials and collectors through 2009, is estimated at $33.1 billion. These estimates include an estimated $3.4 billion capital savings of an aggressive congestion management program.

This scenario would require an average investment of about 1.8 cents per 1989 vehicle mile of travel, compared to about 1.2 cents, or approximately $22 billion, invested in 1989 for similar capital improvements on the same highways.

Exhibit 25 shows investments required to *Maintain Current Condition and Performance* for each functional system. The actual conditions and performance levels maintained in this scenario were presented as the 1989 baseline for the *Improve Conditions and Performance* scenario in Exhibit 24.

Under this scenario, approximately 55 percent of total investment would occur in urban areas, compared to about two-thirds under the *Improve Conditions* scenario. Capacity improvements would account for less than 60 percent of urban investment, compared to over 70 percent under the *Improve Conditions* scenario. Capacity would account for about half of total investment, compared to slightly over 60 percent under the *Improve Conditions* scenario.

System Conditions and Performance Impacts

The *Maintain Condition and Performance* scenario represents an investment level that would substantially halt the current trend in system performance deterioration and maintain the current condition and performance levels, *despite a 65-percent increase in travel demand over the next 20 years.* This means that investments are simulated in response to the impacts of accruing travel demand to maintain 1989 conditions and levels of performance.

Under this strategy, the condition and performance of some roads would improve relative to 1989 and some would deteriorate but, overall, conditions and performance would remain about the same. The overall backlog of highway deficiencies would remain essentially the same over the 20-year analysis period, although some backlog deficiencies would be remedied, according to their cost-effectiveness relative to accruing problems. Currently about 640,000 miles of roadway have pavements rated in "poor" or "low fair" condition, including about 11 percent of Interstate System mileage. Under this scenario, this total would remain almost constant, although highway agencies would likely improve higher volume facilities while delaying needed improvements to lower volume facilities.

System performance would be maintained at its current levels, except in the largest urbanized areas, where right-of-way constraints imposed by the analytical process imply an inability to increase capacity, the same assumption applied under the *Improve Conditions* scenario. This suggests that about 70 percent of urban Interstate peak-hour travel and close to 40 percent of other urban arterial peak-hour travel would remain congested or highly congested, and those figures might actually increase in the largest urbanized areas.

The *Maintain Conditions and Performance* scenario would result in a shortfall of about 22,000 lane-miles of unmet demand in larger urbanized areas, using the capacity expansion constraints discussed under the *Improve Conditions* scenario. Under this scenario, performance in some larger urbanized areas cannot be maintained, even with the capital improvement program and congestion management strategy applied. Exhibit 26 shows current and future lane-miles for this investment strategy.

Exhibit 25
Maintain 1989 Conditions and Performance
2.5% VMT Growth Rate
(billions of 1989 dollars)

Improvements	Capacity	Pavement	Total
Rural			
Interstate	35.6	23.9	59.5
Other Principal Arterial	26.4	22.9	49.3
Minor Arterial	24.1	34.7	58.8
Major Collector	28.6	64.1	92.7
Minor Collector	11.4	26.5	37.9
Subtotal	126.1	172.1	298.2
Urban			
Interstate	52.6	27.6	80.2
Other Freeway & Expressway	28.6	14.9	43.5
Other Principal Arterial	58.5	36.8	95.3
Minor Arterial	43.2	40.6	83.8
Collector	25.6	35.5	61.1
Subtotal	208.5	155.4	363.9
Total	334.6	327.5	662.1
Annual	16.7	16.4	33.1

4,000 miles of new highway capacity is needed each year to maintain today's level of performance.

High occupancy vehicle (HOV) lanes offer an attractive option to peak hour congestion.

Given the current distribution of conditions and high levels of congestion, and the anticipated demands on the system of aging and travel demand, this strategy represents an improvement over recent trends in condition and performance. Holding our own and selectively making improvements in current performance measures is certainly preferable to the continuation of widespread deterioration.

Impact of higher traffic growth rate

Investment requirements are directly related to travel growth between 1990 and 2009. The investment requirements estimates for both scenarios are based on a 2.5 percent average annual travel growth rate. If travel increases at the average annual rate of 3.0 percent, a level more consistent with historic travel growth, the *Improve Conditions and Performance* scenario would cost from $68

Exhibit 26
Total Lane-Mile Requirements Cost to Maintain 1989 Condition And Performance

		2009 Lane-Mile Required		
Functional System	1989	Expansion Capacity	New ROW/Higher Cost Capacity	Total
Rural				
Interstate	134,969	179,809	4,062	183,871
Other Principal Arterial – High	74,095	135,021	4,209	139,230
Other Principal Arterial – Low	131,723	87,309	71	87,380
Minor Arterial	308,266	323,339	5,891	329,230
Major Collector	880,650	892,222	4,835	897,057
Minor Collector	586,998	588,767	274	589,041
Subtotal	2,116,701	2,206,467	19,342	2,225,809
Urban				
Interstate	61,854	77,415	8,889	86,304
Other Freeway & Expressway	33,739	42,226	3,600	45,826
Other Principal Arterial	170,977	190,020	19,175	209,195
Minor Arterial	188,218	211,133	18,076	229,209
Collector	167,699	182,982	12,388	195,370
Subtotal	622,487	703,776	62,128	765,904
Total	2,739,188	2,910,243	81,470	2,991,713

Note: Maximum number of lanes = 12. High principal arterials carry greater than 6,000 vehicles per day. Low principal arterials carry less than or equal to 6,000 vehicles per day.

to $74 billion annually and the *Maintain Conditions and Performance* Scenario would cost $38.8 billion annually.

Bridge Investment Requirements, 1990 - 2009

Backlog

As of December 31, 1989, backlog requirements on the Nation's inventory of arterial, collector, and local road bridges were $91 billion. Of this amount, between 60 and 75 percent was the cost attributable to structural deficiencies. The remainder was the cost attributable to functional obsolescence. The cost of retiring the backlog of bridge deficiencies could increase to as much as $131 billion, depending on the number of years required to meet that objective, because of the deferred capital cost of bridge repair.

Improve Conditions Scenario

The average annual investment required to repair all backlog and accruing bridge deficiencies on all arterial, collector, and local road bridges over the period 1990 to 2009 is between $6 and $8.5 billion, depending on the number of years taken to repair backlog deficiencies.

At these investment levels, all backlog bridge deficiencies would be retired through bridge replacement, rehabilitation, or major widening, and all accruing requirements would be met through 2009. Bridge investment requirements are relatively insensitive to future travel growth.

Of these amounts, between 50 and 75 percent are attributable to structural deficiencies. If bridge structural and deck deficiencies are not identified and repaired in timely fashion, further deterioration could result in major rehabilitation or bridge replacement requirements, which cost significantly more than highway repair, on a unit cost basis. In addition, deferred investment on deficient bridges may impose a public safety hazard that exceeds the risk imposed by a deferred highway improvement. It is for this reason that the deferred capital cost of bridge improvements is significantly higher than similar costs for highways.

Maintain Current Conditions Scenario

The average annual cost to maintain overall bridge conditions as they were reported on December 31, 1989 is estimated at $4.2 billion annually through 2009. This investment level would maintain the current total number and distribution of structurally deficient and functionally obsolete bridges. Between 55 and 75 percent represents costs attributable to structural deficiencies.

Exhibit 27 summarizes 1990 to 2009 investment requirements to eliminate all backlog and accruing bridge deficiencies (*Improve Conditions*) for all bridges greater than 20 feet in length, including those on local roads. All box culverts are also included, regardless of length. Exhibit 28 summarizes the cost to *Maintain Bridge Conditions* as they were reported on June 30, 1990.

Exhibit 27
Cost to Improve Bridge Conditions
1990 - 2009

Functional System	Number of Repaired or Replaced Bridges	1990–2009 Requirements (billions)	Annualized Requirements (billions)
Rural			
Non-Local			
Interstate	11,871	11.1	0.56
Other Principal Arterial	10,828	7.2	0.36
Minor Arterial	11,924	7.1	0.36
Major Collector	56,639	8.0	0.40
Minor Collector	25,940	3.5	0.18
Subtotal Non-Local	117,202	36.9	1.86
Local	127,291	12.0	0.60
Subotal Rural	244,493	48.9	2.46
Urban			
Non-Local			
Interstate	20,156	32.1	1.61
Other Freeway & Expressway	5,682	9.0	0.45
Other Principal Arterial	11,302	15.6	0.78
Minor Arterial	8,370	8.2	0.41
Collector	6,786	3.0	0.15
Subtotal Non-Local	52,296	67.9	3.40
Local	8,480	3.5	0.17
Subtotal Urban	60,776	71.4	3.57
Total Non-Local	169,498	104.8	5.26
Total	305,269	120.3	6.02

Exhibit 28
Cost to Maintain Bridge Conditions
1990 - 2009

Functional System	Number of Repaired or Replaced Bridges	1990–2009 Requirements (billions)	Annualized Requirements (billions)
Rural			
Non-Local			
Interstate	8,293	7.8	0.39
Other Principal Arterial	6,099	4.1	0.20
Minor Arterial	2,131	1.3	0.06
Major Collector	7,570	1.1	0.05
Minor Collector	19,598	2.6	0.13
Subtotal Non-Local	43,691	16.9	0.83
Local	76,188	7.2	0.36
Subtotal Rural	119,879	24.0	1.19
Urban			
Non-Local			
Interstate	19,983	31.8	1.59
Other Freeway & Expressway	5,540	8.8	0.44
Other Principal Arterial	8,977	12.4	0.62
Minor Arterial	3,820	3.7	0.19
Collector	1,629	0.7	0.04
Subtotal Non-Local	39,949	57.4	2.88
Local	6,195	2.5	0.13
Subtotal Urban	46,144	59.9	3.01
Total Non-Local	83,640	74.3	3.71
Total	166,023	84.0	4.2

Other Highway Investment Requirements

The procedures used in this report calculate future urban highway requirements based on current urban boundaries. However, as urban areas grow, rural land adjacent to urban areas takes on the land use and travel character of urban fringe, and fringe areas take on the character of suburban areas. To incorporate the basic infrastructure requirements in expanding suburban areas, which is not included in the earlier highway discussion, a procedure was developed to simulate the expected growth in urban areas and to calculate new lane-miles of roadway that will be required to accommodate the growth at minimum conditions standards. Exhibit 29 summarizes the lane-mile requirements resulting from this procedure.

The HPMS data system does not cover conditions or capital investment requirements for the approximately 2.6 million miles of roads functionally classified as local roads. By FHWA standards, between 35 and 50 percent of all local rural roads are currently in "poor" condition, implying either significantly higher levels of continuing maintenance or capital improvement to restore serviceability or significant deterioration with normal travel demand and weathering. The estimated cost to improve all local roads that are at or near failure is between $8.5 and $12 billion through 2009, or between $425 and $600 million annually in 1989 dollars.

An annual investment of this magnitude would restore serviceability to between 900,000 and 1.3 million miles of local roads that are currently or will become deficient through 2009. The lower estimate is shown in Exhibit 30, the investment summary table, as the local road investment associated with the *Maintain Conditions and Performance* scenario, and the higher estimate is associated with the *Improve Conditions* scenario.

The Nation's highway and bridge systems are an integral part of the national defense transportation system. The military relies on the highway system for peacetime transit of military shipments, as well as for wartime or emergency mobilization and deployment of military units. The STRAHNET, which consists

Exhibit 29
Suburban Highway System Requirements
1990 - 2009

Functional System	New Lane-Miles	Cost ($ billions)
Freeways	12,100	18.8 - 37.7
Other Principal Arterials	15,200	17.5 - 35.4
Minor Arterials	16,400	15.2 - 30.5
Collectors	8,100	8.8 - 17.7
Local Roads	300,000	60.0 - 90.0
Total (Average Annual)	351,800 (17,590)	120.3 - 211.3 (6.0 - 10.5)

of the Interstate System and about 16,800 miles of other principal arterials, is the primary network of defense concern.

An estimated $600 million, or $30 million annually will be required to meet defense specific costs on STRAHNET which include the cost of 12-foot lane-widths where not otherwise required. These are in addition to any estimates shown elsewhere. Not included are costs for the Defense Connector Systems unless those costs are coincident with other HPMS generated estimates.

Total Investment Requirements

Exhibit 30 summarizes annual investment requirements to meet each scenario target for all urban and rural areas. Costs derived from the HPMS and BNIP simulations are presented for each nonlocal functional system. These estimates have been supplemented by separate estimates of investment requirements for local roads, defense highway, and new construction in suburban areas to provide a more complete estimate of total national highway and bridge investment requirements. The estimates incorporate, by functional system, the capital savings associated with the congestion management assumptions.

Exhibit 30
Summary of Annual Highway and Bridge Investment Requirements, 1990 - 2009 (billions of 1989 dollars)

Functional Systems	Cost to Maintain 1989 Conditions and Performance	Cost to Improve 1989 Conditions and Performance
Rural		
Interstate	3.0	3.3
Other Principal Arterial	2.5	3.7
Minor Arterial	2.9	3.7
Major Collector	4.6	5.4
Minor Collector	1.9	3.0
Local Roads	0.2	0.2
Subtotal	15.1	19.3
Urban		
Interstate	5.0	11.7
Other Freeway & Expressway	2.6	4.7
Other Principal Arterial	6.0	13.1
Minor Arterial	5.3	10.3
Collector	3.7	6.0
Local Roads	3.8	3.8
Subtotal	26.4	49.6
Urban and Rural Subtotal	41.5	68.9
Bridge	4.2	6.0
Total Annual Highway and Bridge Requirements	$45.7	$74.9

Chapter 1
System Characteristics Functional and Federal-Aid Systems

Summary

- All public roads and streets in the Nation are functionally classified. There are three major functional systems: arterial, collector, and local. These systems are further subdivided in both rural and urban areas.

- In 1989, there were 3.876 million center-line miles of streets and highways in the United States. Total mileage has decreased by over 3,100 miles since 1983. This represents an annual drop of 0.01 percent. For the same period, mileage in rural areas dropped by over 94,500 miles, or an annual decrease of 0.50 percent. This is attributed to the reclassification of certain United States Forest Service roads to non-public roadways and the reclassification of some facilities from rural to urban. Urban mileage increased by over 91,400 miles (2.18 percent per year).

- Highway lane-mileage reached 8.06 million lane-miles in 1989. This is an increase of 60,000 lane-miles over 1983. This represents an annual growth of 0.12 percent. As with center-line mileage, lane-mileage dropped in rural areas (0.39 percent per year) and increased in urban areas (2.24 percent per year).

- In 1989, the majority of public road and street mileage, 74 percent, fell under local jurisdiction. The States controlled 21 percent of total mileage while only 5 percent fell under Federal jurisdiction.

- Total travel reached 2.11 trillion vehicle miles in 1989—an annual increase of 4.17 percent since 1983. The majority of this travel, 60 percent, occurred in urban areas. Travel in rural areas increased by 3.25 percent per year while travel in urban areas increased by 4.82 percent per year for the 1983-89 period.

- In 1989, trucks accounted for only 7 percent of total travel, but on rural Interstate highways, trucks accounted for almost 20 percent of travel.

- In 1989, the Federal-aid System consisted of over 851,000 center-line miles. The Federal-aid System represented only 22 percent of total national mileage, but it carried 80 percent of total travel. There are four Federal-aid systems: Interstate, primary, secondary, and urban.

- Total Federal-aid System travel reached 1.68 trillion vehicle miles in 1989. Travel on the rural Federal-aid systems represented 33 percent of total vehicle miles traveled in 1989. Travel on the urban Federal-aid systems represented 47 percent of total vehicle miles traveled.

- In 1989, there were over 577,000 bridges in the United States. The majority of these bridges, over 299,000, are under local control. More than 264,000 are under State control while only 2,200 are under Federal control. The remaining bridges are either privately owned, owned by a combination of agencies, or are unclassified as to ownership.

Introduction

This chapter introduces and describes the two overlapping highway classification systems that are used throughout this report: functional and Federal-aid systems. All roads are functionally classified while only those roads and highways that are eligible for Federal-aid are included in the Federal-aid System. Most of the discussion in this report is geared to the various functional systems. Both functional and Federal-aid systems will be examined in terms of mileage, lane-mileage, and travel. Mileage refers to center-line mileage, and lane mileage is the center-line mileage multiplied by the number of through traffic lanes.

Functional Classification

All public roads and streets in the United States are functionally classified by type and use. There are three major functional systems: arterials, collectors, and local roads. These major systems are further subdivided in both rural and urban areas, as is illustrated in Exhibit 1-1. Exhibit 1-2 graphically represents this breakdown by functional system mileage.

Arterial System

Rural Areas

In rural areas, the arterial system is broken down into principal and minor arterials. The rural principal arterial system consists of a connected rural network of continuous routes that have the following characteristics:

1. Serves corridor movements having trip length and travel density characteristics indicative of substantial statewide or interstate travel.
2. Serves all, or virtually all, urban areas with populations greater than 50,000 and a large majority of those with populations greater than 25,000.
3. Provides an integrated network without stub connections except where unusual geographic or traffic flow conditions dictate otherwise (e.g., inter-

national boundary connections and connections to coastal cities, airports, and waterports).

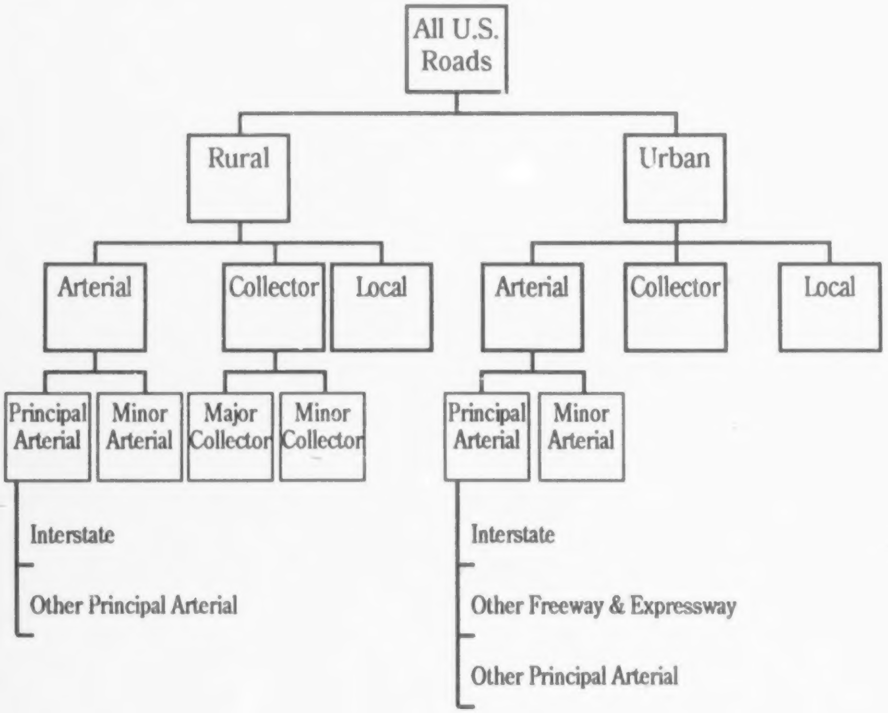
In 1989, the rural principal arterial system accounted for about 4 percent of rural mileage and about 3 percent of total mileage. This small portion of highways carried 42 percent of rural travel and 17 percent of total travel in the Nation.

The rural principal arterial system is stratified into two subsystems: Interstate and other principal arterials.

The rural minor arterial system is made up of routes whose design should be expected to provide for relatively high overall travel speeds, with minimum interference to through-movement. The rural minor arterial system, in conjunction with the principal arterial system, forms a rural network having the following characteristics:

1. Links cities and larger towns (and other traffic generators, such as major resort areas, that are capable of attracting travel over similarly long distances) and forms an integrated network providing interstate and intercounty service.
2. Is spaced at such intervals, consistent with population density, so that all developed areas of the State are within a reasonable distance of an arterial highway.

Exhibit 1-1
Functional Classification Hierarchy


All U.S. Roads
Rural
Urban
Arterial
Collector
Local
Arterial
Collector
Local
Principal Arterial
Minor Arterial
Major Collector
Minor Collector
Principal Arterial
Minor Arterial
Interstate
Other Principal Arterial
Interstate
Other Freeway & Expressway
Other Principal Arterial

Interstate Highway

Other Arterial Highway

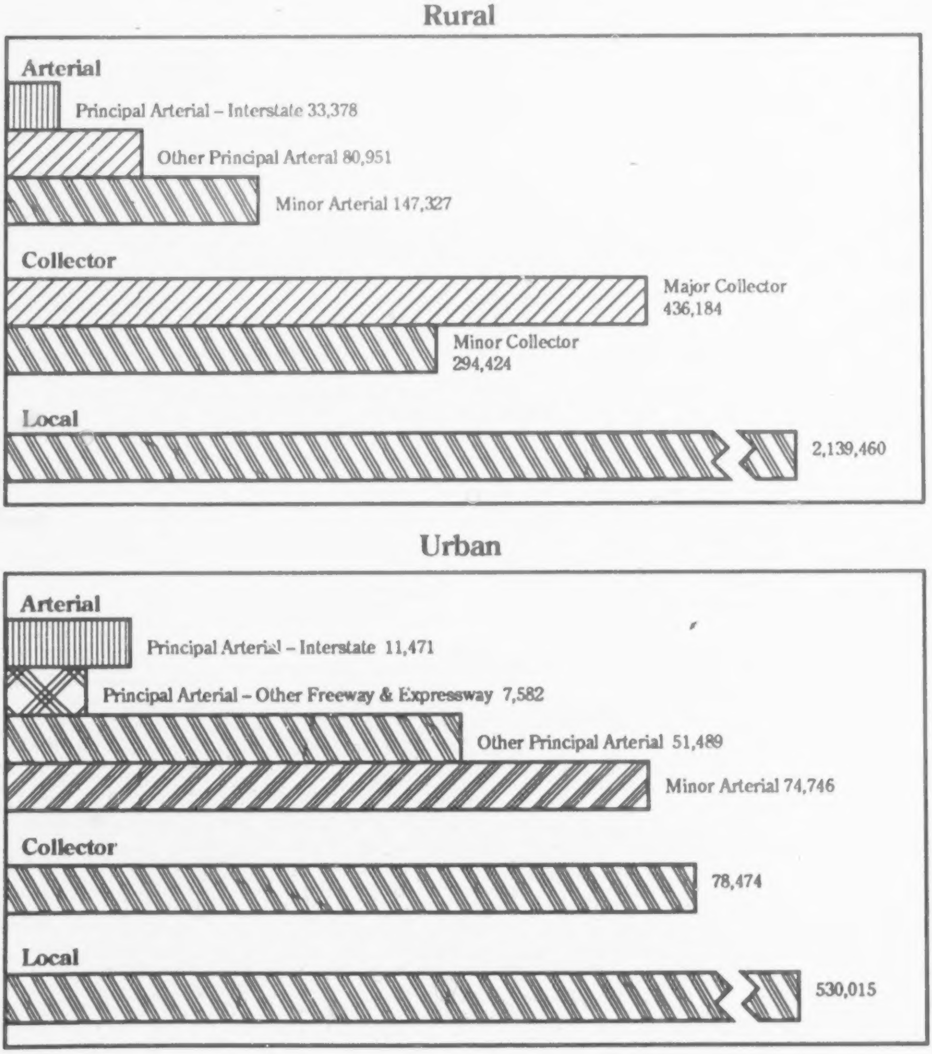
3. Provides service to corridors with trip lengths and travel density greater than those predominantly served by rural collector or local systems.

In 1989, the rural minor arterial system accounted for about 5 percent of rural mileage and about 4 percent of total mileage. It carried 19 percent of rural travel and 7 percent of total travel.

Urban Areas

In urban areas, the arterial system is also broken down into principal and minor arterials. The urban principal arterial system serves the major centers of activity of a metropolitan area, the highest traffic volume corridors, and the

Exhibit 1-2
Highway Mileage by Functional System



longest trip lengths. It carries the major portion of trips entering and leaving the urban area, as well as the majority of through-movements and provides continuity for all rural arterials that intercept the urban boundary.

In 1989, the urban principal arterial system accounted for 9 percent of urban mileage and 2 percent of total mileage. This small amount of mileage carried 57 percent of urban travel and 34 percent of total travel.

The urban principal arterial system is stratified into three subsystems: Interstate, other freeways and expressways, and other principal arterials.

The urban minor arterial system interconnects with and augments the urban principal arterial system and provides service to trips of moderate length at a somewhat lower level of travel mobility. It provides connection to rural collector roads where such connections have not been classified as urban principal arterials.

The urban minor arterial system accounted for 10 percent of urban mileage and 2 percent of total mileage in 1989. It carried 19 percent of urban travel and 11 percent of total travel.

Collector System

Rural Areas

The rural collector system is stratified into two subsystems: major and minor collectors. Major collector routes provide service to any county seat not on an arterial route, to the larger towns not directly served by the higher order systems, and to other traffic generators of equivalent intracounty importance, such as important mining and agricultural areas. Major collector routes link these places to nearby larger towns, cities, or routes of higher classification, and they serve the more important intracounty travel corridors.

Rural minor collector routes are spaced at intervals, consistent with population density, to collect traffic from local roads and bring all developed areas within a reasonable distance of a collector road. They also provide service to the remaining smaller communities.

The rural collector system accounted for 23 percent of rural mileage and 19 percent of total mileage in 1989. It carried 28 percent of rural travel and 11 percent of total travel.

Urban Areas

The urban collector system provides both land access service and traffic circulation within residential neighborhoods and commercial and industrial areas. It differs from the arterial system in that facilities on the collector system may penetrate residential neighborhoods, distributing trips from the arterials through the area to the ultimate destination. The collector system also collects traffic from the local streets and channels it into the arterial system.

Collector Highway

The urban collector system accounted for 10 percent of urban mileage and 2 percent of total mileage in 1989. It carried 8 percent of urban travel and 5 percent of total travel.

Local Roads and Streets

In both rural and urban areas, all mileage below the collector system is classified as local. In 1989, rural local roads accounted for 68 percent of rural mileage and 55 percent of total mileage. These roads carried only 12 percent of rural travel and 5 percent of total travel. Urban local roads accounted for 70 percent of urban mileage and 14 percent of total mileage. These roads carried only 16 percent of urban travel and 10 percent of total travel. Exhibit 1-3 contains a listing of the various functional classifications and their shares of total mileage and travel for 1989.

Mileage and Lane-Mileage Trends

Mileage

In 1989, total public road and street mileage in the Nation reached 3.876 million. Exhibit 1-4 contains a comparison of this mileage by functional classification for the years 1983, 1985, 1987 and 1989. In 1989, almost 81 percent of total mileage fell in rural areas. However, mileage classified as rural has steadily

[illegible]	[illegible]	[illegible]	[illegible]
Subtotal	[illegible]	[illegible]	[illegible]
Urban			
Interstate	[illegible]	[illegible]	[illegible]
Other Freeway & Expressway	[illegible]	[illegible]	[illegible]
Other Principal Arterial	[illegible]	[illegible]	[illegible]
Minor Arterial	1.9	[illegible]	[illegible]
Collector	2.0	2.1	3.8
Local	13.5	15.1	9.6
Subtotal	19.4	20.8	59.7
Total	100.0	100.0	100.0

Source: *Highway Statistics*, 1989.

dropped over the last several years. Over the six-year period from 1983 to 1989, rural mileage has decreased at an annual rate of 0.5 percent. This continuing decrease is attributed to the reclassification of certain United States Forest Service roads to non-public roadways and the reclassification of some facilities from rural to urban due to the expansion of urbanized areas. On a functional system basis, most of this change takes place on lower order systems, particularly local roads. For the same period, urban mileage increased by 2.18 percent per year. Once again, local roads and streets experienced high growth. Excluding local roads, urban Interstate highways experienced the highest growth of all functional systems, with an annual increase in mileage of 1.91 percent. Other than local roads, the largest decrease, 0.32 percent per year, occurred on rural minor collectors. Overall, total mileage decreased by 3,137 miles, which constitutes a decrease of 0.01 percent per year.

Lane-Mileage

Lane-mileage comparisons are found in Exhibit 1-5. In 1989, there were over 8 million lane-miles in the Nation. Over the six-year period from 1983 to 1989, lane-mileage has increased at an annual rate of 0.12 percent. For the same period, lane-mileage increased on all functional systems except rural minor

Exhibit 1-4
Highway Mileage Comparison by Functional System and Year

Functional System	1983	1985	1987	1989	Annual Change 1983 – 89 (%)
Rural					
Interstate	32,788	32,761	33,111	33,378	0.30
Other Principal Arterial	81,234	80,719	80,719	80,951	- 0.06
Minor Arterial	147,536	146,583	147,254	147,327	- 0.02
Major Collector	434,166	432,753	435,413	436,184	0.08
Minor Collector	300,172	296,636	294,799	294,424	- 0.32
Local	2,221,392	2,181,535	2,172,542	2,130,460	- 0.69
Subtotal	3,217,288	3,170,987	3,163,838	3,122,724	- 0.50
Urban					
Interstate	10,240	10,832	11,217	11,471	1.91
Other Freeway & Expressway	7,024	7,170	7,390	7,582	1.28
Other Principal Arterial	47,330	49,895	50,483	51,489	1.41
Minor Arterial	69,108	72,177	74,984	74,746	1.32
Collector	72,513	75,370	76,860	78,474	1.33
Local	456,135	475,503	489,254	530,015	2.53
Subtotal	662,350	690,947	710,188	753,777	2.18
Total	3,879,638	3,861,934	3,874,026	3,876,501	- 0.01

Source: *Highway Statistics*, 1983 – 1989.

arterials and rural local roads. The decrease on the rural systems is attributed to the reclassification of some roads from rural to urban. Lane-mileage in urban areas grew by 2.24 percent per year while rural lane-mileage decreased by 0.39 percent per year. On a functional system basis, the largest increase, 2.53 percent per year, occurred on urban local roads. The largest decrease, 0.69 percent per year, occurred on rural local roads. Excluding local roads, the largest increase, 2.48 percent per year, occurred on urban Interstate highways. The largest decrease, 0.04 percent per year, occurred on urban minor arterials.

Jurisdiction

All public road and street mileage in the United States is also classified by jurisdiction. All mileage is classified as being under either Federal, State, or local control. Comparisons of mileage by jurisdiction and year are found in Exhibit 1-6. For the period 1983 through 1989, the largest annual increase in jurisdictional mileage, 2.61 percent, occurred on urban roads under local control. The largest annual decrease, 6.23 percent, occurred on rural roads under Federal control. This decrease in Federal mileage is attributed to the reclassification of certain United States Forest Service roads to non-public roadways.

Exhibit 1-5

Highway Lane-Mileage Comparison by Functional System and Year

Functional System	1983	1985	1987	1989	Annual Change 1983–89 (%)
Rural					
Interstate	131,976	131,808	133,521	134,969	0.37
Other Principal Arterial	201,414	202,398	203,526	205,818	0.36
Minor Arterial	309,034	307,434	309,031	308,266	- 0.04
Major Collector	867,549	873,187	878,203	880,650	0.25
Minor Collector	574,554	592,124	587,686	586,998	0.36
Local	4,442,784	4,363,070	4,345,084	4,260,920	- 0.69
Subtotal	6,527,311	6,470,021	6,457,051	6,377,621	- 0.39
Urban					
Interstate	53,386	57,327	59,831	61,854	2.48
Other Freeway & Expressway	30,817	31,598	32,569	33,739	1.52
Other Principal Arterial	150,892	159,264	166,461	170,977	2.10
Minor Arterial	172,395	180,940	190,751	188,218	1.47
Collector	153,118	162,203	164,395	167,699	1.53
Local	912,270	951,006	978,508	1,060,030	2.53
Subtotal	1,472,878	1,542,338	1,592,515	1,682,517	2.24
Total	8,000,189	8,012,359	8,049,566	8,060,138	0.12

Note: For local roads, the number of lanes is assumed to be 2.

Source: *Highway Statistics*, 1983 – 89.

Travel Trends

Travel comparisons are found in Exhibit 1-7. In 1989, total travel reached 2.11 trillion vehicle miles. For the six-year period from 1983 to 1989, total travel increased at an annual rate of 4.17 percent. For the same period, travel increased across all functional systems. Travel growth in urban areas continued to outpace rural areas. Urban travel increased 4.82 percent per year while rural travel increased 3.25 percent per year. On a functional system basis, the largest annual increase, 6.31 percent, occurred on urban local roads. Excluding local roads, urban Interstate highways experienced the largest annual growth, 5.97 percent. Rural minor collectors experienced the smallest annual growth, 1.57 percent.

Exhibit 1-8 presents daily travel per lane-mile for each functional system. Daily travel per lane-mile is equivalent to annual average daily traffic (AADT) per lane. On a per-lane-mile basis, urban Interstate highways by far carry the most travel. Excluding the local roads, the rural Interstate System showed the largest annual growth in travel on a per-lane-mile basis. Between 1983 and 1989, travel per lane-mile on rural Interstate highways increased by 4.38 percent per year. Although the amount of travel has increased more in urban areas than in rural areas, on a per-lane-mile basis rural travel growth has outpaced urban travel growth. Between 1983 and 1989, rural travel per lane-mile increased by 3.67 percent per year while urban travel per lane-mile increased by only 2.57 percent per year.

Exhibit 1-6
Highway Mileage Comparison by Jurisdiction and Year

Functional System	1983	1985	1987	1989	Annual Change 1983 – 89 (%)
Rural					
Federal	262,122	225,122	211,511	178,189	- 6.23
State	817,206	773,249	703,554	706,506	- 2.40
Local	2,137,960	2,172,616	2,248,773	2,238,029	0.77
Subtotal	3,217,288	3,170,987	3,163,838	3,122,724	- 0.50
Urban					
Federal	893	1,035	1,045	1,026	2.34
State	99,627	111,496	95,442	96,901	- 0.46
Local	561,830	578,416	613,701	655,850	2.61
Subtotal	662,350	690,947	710,188	753,777	2.18
Total	3,879,638	3,861,934	3,874,026	3,876,501	- 0.01

Source: *Highway Statistics*, 1983 – 1989.

Truck Travel

Truck travel is an important factor affecting highway needs on the various functional systems. Exhibit 1-9 contains a breakdown of travel by vehicle type and road type for the years 1985, 1987, and 1989. Combination trucks are used primarily for intercity freight transportation, and their travel is concentrated on rural arterial highways. In 1989, combination trucks accounted for 16 percent of total travel on rural Interstate highways, but only 6 percent of travel on urban Interstate highways. Single unit trucks are used primarily for local transportation. Whereas half of all combination truck travel is on Interstate highways, less than 25 percent of travel by single unit trucks is on the Interstate System.

Combination truck travel grew at an annual rate of 4.68 percent between 1985 and 1989. This was somewhat greater than the 4.41 percent annual growth for passenger vehicles. For the same period, travel by single unit trucks increased at an annual rate of 3.15 percent.

Exhibit 1-7
Highway Travel Comparison by Functional System and Year (Travel in millions of annual vehicle miles)

Functional System	1983	1985	1987	1989	%Annual Change 1983 – 89 (%)
Rural					
Interstate	144,733	154,148	171,866	191,120	4.74
Other Principal Arterial	139,962	145,903	155,446	165,993	2.88
Minor Arterial	133,421	136,854	146,528	156,626	2.71
Major Collector	156,786	163,197	174,176	187,182	3.00
Minor Collector	43,806	43,345	44,488	48,085	1.57
Local	81,825	86,868	89,243	99,877	3.38
Subtotal	700,533	730,315	781,747	848,883	3.25
Urban					
Interstate	191,149	216,441	245,339	270,652	5.97
Other Freeway & Expressway	86,790	97,351	109,900	122,055	5.85
Other Principal Arterial	255,327	279,025	304,673	326,897	4.20
Minor Arterial	188,467	201,738	224,107	234,863	3.74
Collector	86,593	89,531	95,964	101,259	2.64
Local	140,247	160,361	162,597	202,431	6.31
Subtotal	948,573	1,044,447	1,142,580	1,258,157	4.82
Total	1,649,106	1,774,762	1,924,327	2,107,040	4.17

Source: *Highway Statistics*, 1983 – 1989.

The Federal-Aid System

The Federal-aid System consists of those roadways that are eligible for Federal-aid. The Federal-aid Highway System is divided into four administrative classifications: Interstate, primary, secondary, and urban. Identification of a road as part of one of these Federal-aid highway systems is the first action a State takes in making the facility eligible for Federal-aid. Although all roads that are functionally classified as arterials or collectors are eligible for inclusion, not all eligible roads are part of the Federal-aid System. Exhibits 1-10 and 1-11 shows mileage on and off the Federal-aid System by functional classification.

Exhibit 1-8

Daily Travel per Highway Lane-Mile Comparison by Functional System and Year (Thousands of daily VMT per lane-mile)

Functional System	1983	1985	1987	1989	Annual Change 1983 – 89 (%)
Rural					
Interstate	3.00	3.20	3.53	3.88	4.38
Other Principal Arterial	1.90	1.97	2.09	2.21	2.55
Minor Arterial	1.18	1.22	1.30	1.39	2.77
Major Collector	0.50	0.51	0.54	0.58	2.50
Minor Collector	0.21	0.20	0.21	0.22	0.78
Local	0.05	0.05	0.06	0.06	3.09
Subtotal	0.29	0.31	0.33	0.36	3.67
Urban					
Interstate	9.81	10.34	11.23	11.99	3.40
Other Freeway & Expressway	7.72	8.44	9.24	9.91	4.25
Other Principal Arterial	4.64	4.80	5.01	5.24	2.05
Minor Arterial	3.00	3.05	3.22	3.42	2.21
Collector	1.55	1.51	1.60	1.65	1.05
Local	0.42	0.46	0.46	0.52	3.62
Subtotal	1.76	1.86	1.97	2.05	2.57
Total	0.56	0.61	0.65	0.72	4.28

Source: *Highway Statistics*, 1983 – 1989.

Exhibit 1-9
Travel by Location and Vehicle Type
(in millions of annual vehicle miles)

Functional System	1985			1987			1989			Annual Change 1985-89		
	PV	SU	Combo	PV	SU	Combo	PV	SU	Combo	PV	SU	Combo
Rural												
Interstate	123,336	4,992	25,947	139,054	5,299	27,513	155,538	5,825	29,757	5.97	3.93	3.48
Other Arterials	255,002	9,702	17,891	272,328	10,304	19,342	291,521	10,879	20,219	3.40	2.90	3.11
Other Rural	273,750	10,820	8,761	287,000	11,567	9,340	311,988	12,564	10,592	3.32	3.81	4.86
Subtotal	652,088	25,514	52,599	698,382	27,170	56,195	759,047	29,268	60,568	3.87	3.49	3.59
Urban												
Interstate	198,042	5,212	12,906	225,234	5,681	14,784	247,259	6,227	17,166	5.71	4.55	7.39
Other Urban	797,469	16,254	14,095	865,124	16,762	15,355	951,977	17,695	17,833	4.53	2.15	6.06
Subtotal	995,511	21,466	27,001	1,090,358	22,443	30,139	1,199,236	23,922	34,999	4.76	2.75	6.70
Total	1,647,599	46,980	79,600	1,788,740	49,613	86,334	1,958,283	53,190	95,567	4.41	3.15	4.68

Note: PV = Passenger Vehicles, SU = Single Unit Trucks, Combo = Combination Trucks. Complete data not available for 1983.

Source: *Highway Statistics*, 1985 – 1989.

Interstate System

In 1989, the Interstate System contained 44,849 miles of limited access arterial highways linking major population, industrial, and defense centers. The Interstate System was designed to serve interstate commerce, national defense, and international transportation. The highest physical geometric standards are found on the Interstate System. In 1989, over 99 percent of the mileage had lane widths of 12 feet or more with over 98 percent of the mileage having alignment that meets design standards for grade and curve safety at prevailing speed limits.

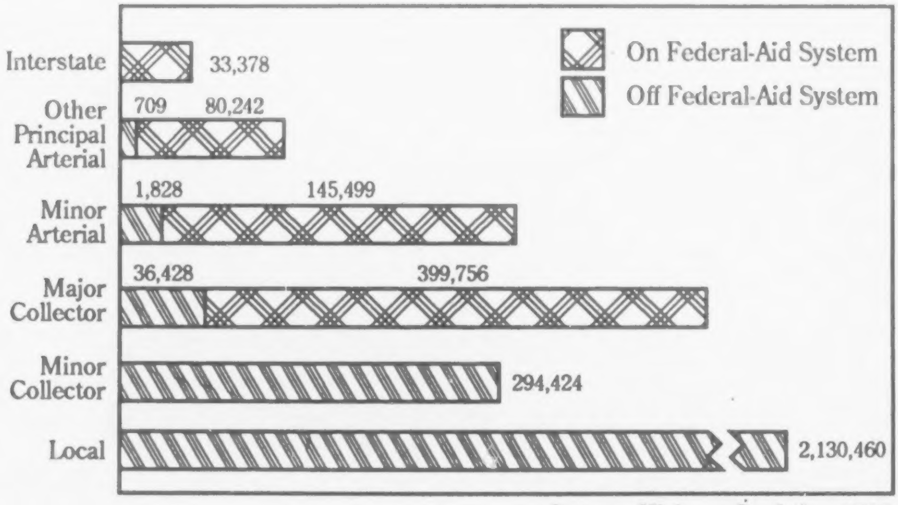
The Interstate System comprised 5.3 percent of total Federal-aid mileage (1.2 percent of total public mileage) and carried 27 percent of total Federal-aid System travel in 1989. Most of the mileage, 74 percent, was located in rural areas, and 41 percent of annual Interstate vehicle miles of travel occurred in rural areas. In urban areas, where the remaining 26 percent of Interstate mileage was located, 59 percent of the annual Interstate travel occurred. Of total urban travel on all public roads, 21 percent occurred on urban Interstate highways in 1989. From 1983 to 1989, travel on the Interstate System increased at an annual rate of 4.74 percent in rural areas and 5.97 percent in urban areas.

Primary System

The original Federal-aid Highway System, the primary system, dates to the Federal Highway Act of 1921. This Act required a system of interconnected roads, interstate in character, to be designated by the States with mileage not

Exhibit 1-10
Mileage by Functional and Federal-Aid System

Rural (1989)



Source: Highway Statistics, 1989

to exceed 7 percent of total mileage in each State. There are no longer statutory limits on mileage.

Today, the primary system generally consists of both urban and rural arterial routes serving interstate, regional, and statewide travel. In 1989, the primary routes represented 7 percent of the total public road and street mileage in the Nation and 30 percent of total Federal-aid System mileage. The Federal-aid Primary System consisted of 259,205 miles of highway in 1989. The majority of this mileage, 87 percent, was found in rural areas with the remaining 13 percent falling in urban areas.

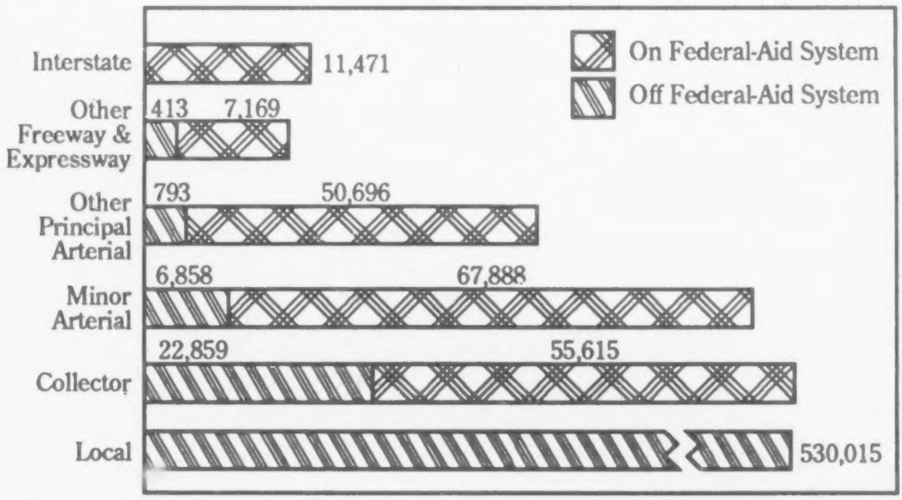
Travel on the primary system has increased from 483 billion vehicle miles in 1983 to 584 billion vehicle miles in 1989, an annual increase of 3.22 percent. In 1989, this represented 28 percent of total national travel. For the same period, travel increased by 2.75 percent per year on rural primary highways and by 3.85 percent per year on urban primary highways.

Secondary System

Established in 1944, the secondary program originally was conceived to meet farm-to-market needs, but because of the broad eligibility criteria used, it became a mixture of facilities from local access roads to high-order arterials. Realigned by congressional mandate in 1976, the system consisted of 399,756 miles of rural major collector routes in 1989 (47 percent of total Federal-aid mileage). Secondary system roads, while not forming an interconnected network, provide the following:

Exhibit 1-11
Mileage by Functional and Federal–Aid System

Urban (1989)



Source: Highway Statistics, 1989

- Collector service to the rest of the Federal-aid System,
- Intracounty connectivity,
- Service to county seats and other large traffic generators not on the primary system,
- Service to intracounty traffic corridors, and
- Connections to higher order systems.

Typically, a secondary system road has two lanes, is paved with an intermediate type of surface, and is not designed to carry heavy axle loads.

While the secondary system made up 10.3 percent of total public mileage, it carried only 8.5 percent of total travel in 1989. Travel on the system rose from 148 billion vehicle miles in 1983 to 179 billion vehicle miles in 1989, an annual increase of 3.22 percent.

Urban System

The Federal-aid Urban System (FAUS) was established by the Federal-aid Highway Act of 1970 to address the transportation requirements of urban areas. The FAUS serves major urban activity centers and includes high traffic volume arterial and collector routes such as access roads to airports and other transportation terminals. Routes are selected by local and State officials to aid intracity movements. No route on the FAUS is on another Federal-aid system.

In 1989, the FAUS consisted of 147,904 miles of highway functionally classified as other freeway and expressway (750 miles), other principal arterial (25,211 miles), minor arterial (66,328 miles), and collector (55,615 miles). Between 1983 and 1989, travel on the FAUS increased from 360 billion vehicle miles to 463 billion vehicle miles, an annual increase of 4.29 percent.

Federal-Aid System Mileage

The Federal-aid System consisted of 851,714 miles of highway in 1989. Exhibit 1-12 contains a cross-classification of mileage between functional and Federal-aid systems. Total Federal-aid System mileage represented 22 percent of the total 3,876,501 public highway mileage in the Nation. Most of the system mileage, 77 percent, was in rural areas. The Federal-aid rural mileage represented 21 percent of total rural public mileage. The remainder of Federal-aid System mileage, 23 percent, fell in urban areas. The Federal-aid urban mileage represented 26 percent of total urban public mileage.

Federal-Aid System Travel

Although the Federal-aid System comprises only about 22 percent of total public road mileage in the Nation, it carries 80 percent of all travel. Exhibit 1-13

Exhibit 1-12
1989 Mileage by Functional System and Federal-Aid System

Functional System	Federal-Aid System					Non Federal Aid	Total
	Interstate	Primary	Urban	Secondary	Federal Aid Total		
Rural							
Interstate	33,378	—	—	—	33,378	—	33,378
Other Principal Arterial	—	80,242	—	—	80,242	709	80,951
Minor Arterial	—	145,499	—	—	145,499	1,828	147,327
Major Collector	—	—	—	399,756	399,756	36,428	436,184
Minor Collector	—	—	—	—	—	294,424	294,424
Local	—	—	—	—	—	2,130,460	2,130,460
Subtotal	33,378	225,741	—	399,756	658,875	2,463,849	3,122,724
Urban							
Interstate	11,471	—	—	—	11,471	—	11,471
Other Freeway & Expressway	—	6,419	750	—	7,169	413	7,582
Other Principal Arterial	—	25,485	25,211	—	50,696	793	51,489
Minor Arterial	—	1,560	66,328	—	67,888	6,858	74,746
Collector	—	—	55,615	—	55,615	22,859	78,474
Local	—	—	—	—	—	530,015	530,015
Subtotal	11,471	33,464	147,904	—	192,694	560,938	753,632
Total	44,849	259,205	147,904	399,756	851,714	3,024,787	3,876,501

Source: *Highway Statistics*, 1989.

contains a cross-classification of travel between functional and Federal-aid systems. In 1989, the Interstate system continued to serve the bulk of national travel, carrying 27 percent of Federal-aid System travel and 22 percent of total travel. The primary system carried 35 percent of Federal-aid System travel and 28 percent of total travel. The secondary system carried 11 percent of Federal-aid System travel and 9 percent of total travel while the FAUS carried 27 percent of Federal-aid System travel and 22 percent of total travel.

Exhibit 1-14 contains a listing of travel, lane-mileage, and travel per-lane-mile for the Federal-aid systems. On a per-lane-mile basis, the largest amount of travel occurs on urban Interstate highways, which carry almost 12,000 daily VMT per lane-mile. Excluding non- Federal-aid highways, the smallest amount of travel per lane-mile occurs on the secondary system, which carries only 600 daily VMT per lane-mile.

Bridges

In 1989 there were more than 577,000 bridges on our Nation's highways. Information on the condition and characteristics of these bridges is contained in the National Bridge Inventory (NBI), which is updated continuously by the States. Exhibit 1-15 contains a listing of these bridges by functional and Federal-aid systems. Exhibit 1-16 contains a listing of bridges by jurisdiction. The majority of these bridges, over 299,000, are under local jurisdiction. More than 264,000 bridges fall under State jurisdiction while only 2,200 fall under Federal jurisdiction. More than 3,500 bridges are privately owned and over 2,300 bridges are owned by a combination of agencies. There are 5,700 bridges whose ownership is unclassified or unknown.

· Exhibit 1-13

1989 Travel by Functional System and Federal-Aid System

(Travel in millions of annual vehicle miles)

Functional System	Federal-Aid System Interstate	Primary	Urban	Secondary	Federal Aid Total	Non Federal Aid	Total
Rural							
Interstate	191,120	—	—	—	191,120	—	191,120
Other Principal Arterial	—	162,628	—	—	162,628	3,365	165,993
Minor Arterial	—	155,209	—	—	155,209	1,417	156,626
Major Collector	—	—	—	179,300	179,300	7,882	187,192
Minor Collector	—	—	—	—	—	48,085	48,085
Local	—	—	—	—	—	99,877	99,877
Subtotal	191,120	317,837		179,300	688,257	160,626	848,883
Urban							
Interstate	270,652	—	—	—	270,652	—	270,652
Other Freeway & Expressway	—	104,563	11,194	—	115,757	6,298	122,055
Other Principal Arterial	—	155,257	167,916	—	323,173	3,724	326,897
Minor Arterial	—	6,633	209,543	—	216,176	18,687	234,863
Collector	—	—	74,688	—	74,688	26,571	101,259
Local	—	—	—	—	—	202,431	202,431
Subtotal	270,652	266,453	463,341		1,000,466	257,711	1,258,157
Total	461,772	584,290	463,341	179,300	1,688,703	418,337	2,107,040

Source: *Highway Statistics*, 1989.

Exhibit 1-14
1989 Travel, Lane-Mileage, and Travel per Lane-Mile by Federal-Aid System
(Travel in millions of annual vehicle miles and thousands of daily VMT per mile)

Federal-aid System	Travel	Lane-Miles	Travel per Lane-Mile
Rural			
Interstate	191,120	134,969	3.88
Primary	317,837	508,141	1.71
Secondary	179,300	808,006	0.61
Non Federal-Aid	160,626	4,926,505	0.09
Subtotal	848,883	6,377,621	0.36
Urban			
Interstate	270,652	61,854	11.99
Primary	266,453	116,730	6.25
Urban	463,341	370,309	3.43
Non Federal-Aid	257,711	1,133,624	0.62
Subtotal	1,258,157	1,682,517	2.05
Total	2,107,040	8,060,138	0.72

Source: *Highway Statistics*, 1989.

Exhibit 1-15
1989 Bridges by Functional System and Federal-Aid System

Functional System	Federal-Aid System Interstate	Primary	Urban	Secondary	Federal Aid Total	Non Federal Aid	UC*	Total
Rural								
Interstate	29,816	—	—	—	29,816	—	—	29,816
Other Principal Arterial	—	32,109	—	—	32,109	546	2	32,657
Minor Arterial	—	37,539	—	—	37,539	1,219	—	38,758
Major Collector	—	—	—	91,133	91,133	16,478	2	107,613
Minor Collector	—	—	—	—	—	47,202	3	47,205
Local	—	—	—	—	—	208,323	46	208,369
Unclassified	—	196	—	325	521	1,735	34	2,290
Subtotal	29,816	69,844		91,458	191,118	275,503	87	466,708
Urban								
Interstate	23,685	—	—	—	23,685	—	—	23,685
Other Freeway & Expressway	—	8,622	1,441	—	10,063	452	3	10,518
Other Principal Arterial	—	12,223	8,338	—	20,561	929	3	21,493
Minor Arterial	—	2,116	15,929	—	18,045	1,200	3	19,248
Collector	—	—	11,735	—	11,735	2,319	3	14,057
Local	—	—	—	—		18,080	8	18,088
Unclassified	—	163	379	—	542	2,949	8	3,499
Subtotal	23,685	23,124	37,822		84,631	25,929	28	110,588
Total	53,501	92,968	37,822	91,458	275,749	301,432	115	577,296

*Unclassified.

Source: *Highway Statistics*, 1989.

Exhibit 1-16
1989 Bridges by Jurisdiction

Owner	Number of Bridges
Federal	2,204
State	264,417
Local	299,083
Private	3,568
Combination	2,324
Unknown/Unclassified	5,701
Total	577,297

Source: FHWA estimate, *Highway Statistics*, 1989

Chapter 2
Highway Finance

Summary

- **Public Sector Financing** — In 1989, all levels of government spent $67.7 billion on highway programs. Constant dollar spending on highways increased from $27.5 billion in 1960 to $36.7 billion in 1989. However, highway spending patterns have been erratic and in several years during this period actually declined below the 1960 level. In constant dollars per unit of travel, expenditures have dropped by more than one-half since 1960.

- **Public Sector Revenue Sources** — Revenue for public sector highway programs come from a variety of sources including user charges, benefit charges, investments and miscellaneous fees, bond issues, and non-highway based revenue instruments. User charges including motor fuel taxes, motor vehicle taxes, and tolls accounted for 60 percent of revenues. General funds and other non-highway based revenue instruments are the next largest source of revenue (16 percent). Benefit charges including private cost sharing provides 9 percent, investment income and miscellaneous fees 8 percent, and bond issuances 7 percent.

- **Revenue Trends for Selected Highway User Revenue Sources** — Total revenues from user charges increased in constant dollars from $22.8 billion in 1960 to $29.4 billion in 1989. Revenues from this source used for highways was $22.0 billion in 1960 and $24.7 billion in 1989. In 1960, 3.5 percent of constant dollar revenues from user charges were not spent on highways. By 1989, the percent of revenues being diverted from use for highways had increased to 16 percent.

- **Highway Noncapital Expenditures and Trends** — Noncapital highway expenditures include maintenance and operations of highways, administration, highway law enforcement, safety, and debt service on highway bonds and notes. Routine roadway maintenance takes the largest share of noncapital outlays and is not eligible for Federal-aid. The noncapital highway bill for the public sector was $38 billion in 1989 or 53 percent of all highway expenditures.

- **Highway Capital Expenditures** — All governments spent over $33 billion on capital outlay in 1989. Capital outlay includes projects that add capacity to the system as well as those that preserve the existing physical conditions. Capacity improvements include reconstruction with added lanes and wider lanes, major widening, and new construction on new right-of-way. Preservation improvements include pavement reconstruction, and resurfacing. On non-local roads, 53 percent of spending is for capacity improvements.

Highway capital outlay per mile of travel has decreased over 60 percent in constant dollars since 1960. This pattern was reversed in the 1980's.

- **Capital Financing by Level of Government**—The Federal government provided 43 percent of the total highway capital outlay of $33 billion in 1989. The Federal share of capital outlay reached 56 percent in 1980 and remained close to this level until 1985. Since 1985, the Federal share of capital outlay has declined annually.

- **Highway Capital Outlay on Federal-Aid Systems** — Of the $33 billion spent on capital outlay by the public sector in 1989, $25 billion was spent on the Federal-aid systems. The largest expenditure was on the Federal-aid Primary System. Spending for capacity improvements on the Federal-aid system was 54 percent of total expenditures, similar to the spending pattern on all non-local roads.

- **Private Sector Financing of Highways** — Private sector financing includes projects funded and developed by the private sector, e.g., local roads that are part of a development project, intersection improvements required by a development agreement, improvements to intersections, a toll road developed by private investors, etc. It has been estimated that $9.6 billion of highway improvements was financed by the private sector in 1989. Combined public and private sector financing for highways was approximately $83.2 billion in 1989.

Introduction

Chapter 2 provides an overview of the current financing structure for highways. Financing for roads and highways comes from both the public and private sectors. Previous needs reports have focused exclusively on public sector financing. However, because of the growing involvement of the private sector in providing needed highway capacity, a discussion of both public and private sector financing will be included in this chapter.

Beginning with public sector financing, the chapter considers the various revenue sources, and revenues from these sources that are used for highways. This is followed by an analysis of trends for some of these sources with attention focused on highway user charges.

Expenditures for highways are addressed and are disaggregated into noncapital and capital outlays. For capital outlays, trends are identified and the source of funds by level of government is shown. A discussion of capital outlay on the Federal-aid System by level of government and type of improvement follows.

The chapter ends with a brief discussion of private sector financing and combined public and private sector financing.

Constant dollar values were calculated using "Price Trends for Federal-aid Highway Construction (1977 Base)."

Public Sector Financing of Highways

This section presents an overview of public sector financing of highways in 1989 and trends in highway financing since 1960. Public sector financing includes all funding for highways that is managed by the public sector including projects built with revenue from exactions, development fees, special district assessments, etc.

In 1989, all levels of government provided $73.6 billion for highway programs. The Federal Government funded $16.5 billion, the States $36.9 billion, and counties, cities, and other local entities funded the remaining $20.2 billion. Federal funds, primarily supplied by the Highway Trust Fund, accounted for 22.5 percent of the total funding for highways in 1989, down from 24.8 percent in 1980. The States accounted for one-half of all funding for highways; a ratio unchanged over the last decade. Since 1980, local governments have almost doubled their funding for highways and raised their share of total funding from 25.7 to 27.4 percent. See Exhibit 2-1.

Of the total $73.6 billion allocated for highways in 1989, $2.4 billion was placed in reserve and $3.5 billion was used for debt retirement leaving a balance of $67.7 billion to be spent on highway programs.

Trends in Highway Financing

In current dollars, highway spending by all governments totaled $10.2 billion in 1960. For 1989 the amount was $67.7 billion. In constant dollars, highway spending increased from $27.5 billion in 1960 to $36.7 billion in 1989. However, there have been three distinct cycles in highway spending during this period with the first beginning in 1960 and ending in the mid-1970's, the second continuing from the mid-1970's to 1980, and the third starting in 1980 and continuing through 1989 (see Exhibit 2-2). Spending in several years during this period declined below the 1960 level. Since 1980, constant dollar spending has been increasing almost annually.

In constant dollars, per unit of travel, expenditures have dropped by more than one-half since 1960 (see Exhibit 2-3). Constant dollar expenditures per unit of travel increased slowly from 1980 through 1985 but since then have experienced a gradual decline.

Revenue Sources for Public Sector Financing of Highways

This section discusses the various revenue sources for public sector financing of highways and, where data are available, the revenue generated by each source **that is used for highways**. Exhibit 2-4 provides an overview of these revenue sources.

Funding for the $73.6 billion appropriated for highway programs in 1989 came from a number of sources including user charges, general funds and other non-highway based revenue instruments, benefit charges, investments and miscellaneous fees, and bond issues.

User Charges

User charges are the largest single source of revenue for public sector financing of highways. User charges include imposts levied on owners and operators of motor vehicles because of their use of the public highways. These

Exhibit 2-1
Funding for Highways by Government Jurisdiction for Selected Years (in millions of dollars)

	Federal		State		Local		Total	
Year	Receipts	Percent	Receipts	Percent	Receipts	Percent	Receipts	Percent
1960	3,063	26.7	6,055	52.7	2,367	20.6	11,485	100.0
1964	3,907	28.5	7,192	52.5	2,594	18.9	13,693	100.0
1968	5,064	27.2	10,036	53.9	3,534	19.0	18,634	100.0
1972	6,286	25.7	13,551	55.3	4,646	19.0	24,483	100.0
1974	7,846	28.4	14,238	51.6	5,498	19.9	27,582	100.0
1976	8,038	26.1	16,126	52.3	6,667	21.6	30,831	100.0
1978	9,750	27.5	17,766	50.0	7,988	22.5	35,504	100.0
1980	9,830	24.8	19,666	49.5	10,219	25.7	39,715	100.0
1981	10,338	24.2	21,044	49.3	11,311	26.5	42,693	100.0
1982	10,110	22.9	22,078	50.1	11,867	26.9	44,055	100.0
1983	11,684	24.3	23,918	49.8	12,471	25.9	48,073	100.0
1984	14,698	26.9	26,550	48.6	13,388	24.5	54,636	100.0
1985	14,749	24.1	30,543	49.9	15,933	26.0	61,225	100.0
1986	14,986	22.7	32,493	49.5	18,302	27.8	65,781	100.0
1987	14,466	21.7	32,788	49.3	18,280	29.0	65,534	100.0
1988	15,695	22.4	34,670	49.6	19,578	28.0	69,943	100.0
1989	16,535	22.5	36,906	50.1	20,192	27.4	73,633	100.0

Source: *Highway Statistics*, HF-11, various years; and HF-10, October 1990.

Exhibit 2-2
Highway Expenditures All Units of Government

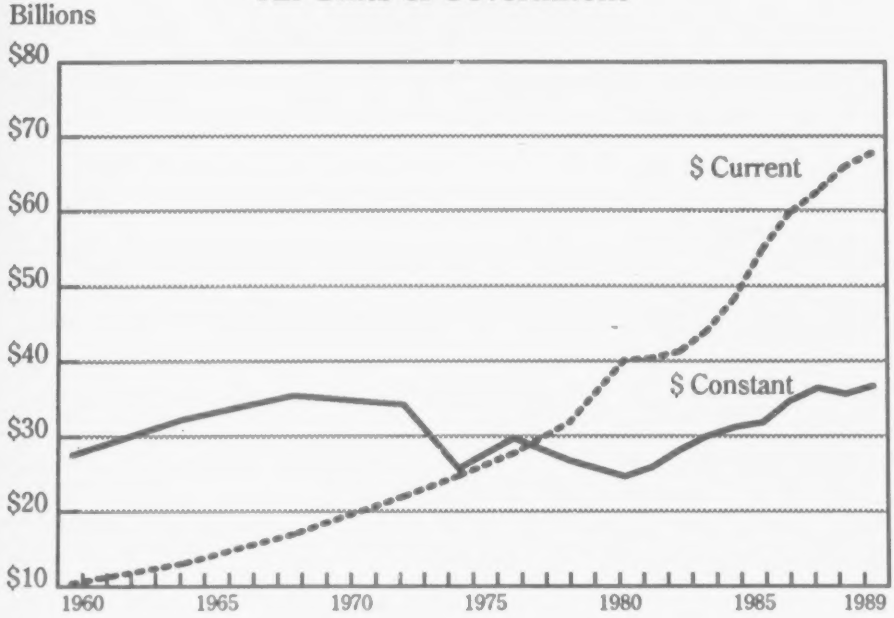


Exhibit 2-3
Highway Expenditures per Unit of Travel

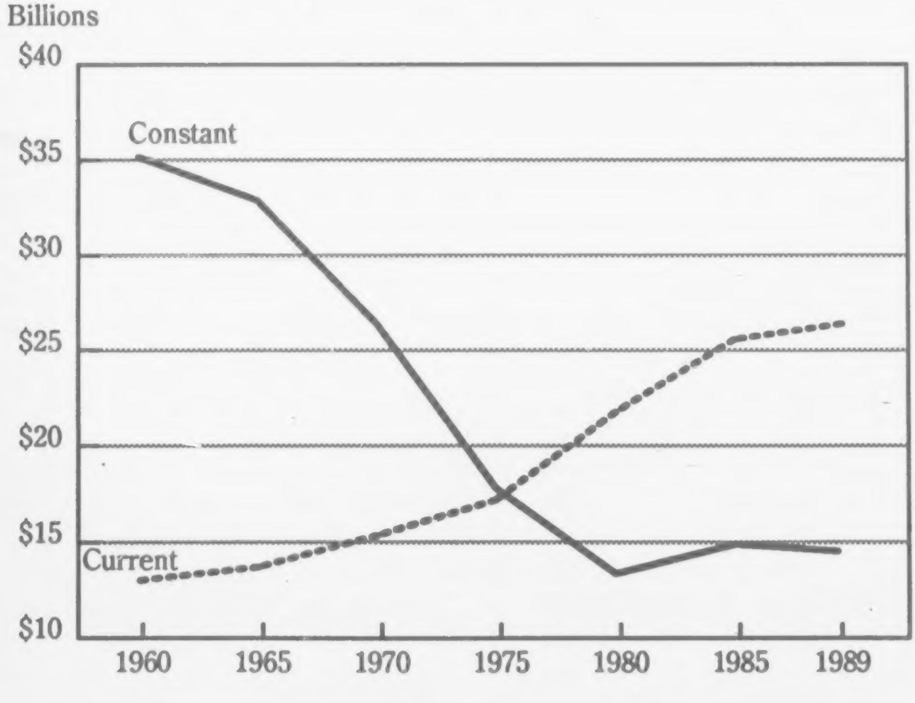


Exhibit 2-4
Revenue Sources for Public Sector Financing of Highways – 1989 ($ in billions)

	Federal	State	Local	Total	Percent
1. User Charges:					
Motor Fuel Taxes	11.92	17.03	0.54	29.49	40%
Motor Vehicle Taxes	2.20	9.32	0.32	11.84	16%
Tolls	–	2.50	0.51	3.01	4%
Subtotal	14.12	28.85	1.37	44.34	60%
2. General Funds and Other Non-Highway Based Revenue Instruments	0.99	1.52	8.95	11.46	16%
3. Benefit Charges:					
Property Taxes and Assessments	–	–	4.54	4.54	6%
Other Taxes and Fees	0.07	1.37	1.01	2.45	3%
Subtotal	0.07	1.37	5.55	6.99	9%
4. Investment Income and Miscellaneous Receipts	1.36	2.09	2.33	5.78	8%
5. Bond Issue Proceeds	–	3.06	2.00	5.06	7%
Total	16.54	36.89	20.20	73.63	100%

Source: *Highway Statistics, 1989*, Table HF-10

imposts consist chiefly of motor-fuel taxes, registration fees, driver license fees, weight-distance taxes, titling taxes, other fees closely connected to the ownership and operation of motor vehicles, and tolls. For purposes of this discussion, user charges are grouped into three categories: motor vehicle taxes and fees, motor fuel taxes, and tolls. Exhibit 2-5 shows total revenues from these sources by level of government.

While $54.2 billion was raised from these revenue sources in 1989, only $44.3 billion was used for highways. Exhibit 2-6 includes only those revenues raised from user charges in 1989 that were used for highways.

Motor-Fuel Taxes

Motor fuel taxes are imposed on highway usage of **gasoline, diesel, gasohol, and other special fuels** with the largest share of revenue coming from gasoline and diesel fuel taxes. This revenue source is used by all three levels of government. The excise taxes imposed on each type of fuel differs depending on the governmental level and jurisdiction.

Total *gasoline* excise taxes paid at retail include the Federal tax (9.1 cents)[1], the State tax (14.19 cents weighted national average based on fuel consumption by States for 1989)[2], and any local tax. The Federal tax is uniformly applied throughout the United States. State and local taxes vary.

Current State gasoline excise taxes range from 7.5 cents to 23 cents. Some States permit local option gas taxes and local governments have elected to use this option in 13 States. Exhibit 2-7 provides State tax rates.

The Federal *diesel* tax is 15.1 cents a gallon[3]. The weighted national average State special fuel (diesel) tax is 14.76 cents a gallon, slightly more than the State gasoline tax.

Exhibit 2-5
Total Revenue from User Charges – 1989
($ in billions)

	Federal	State	Local [1]	Total
Motor Fuel Taxes	$13.42	$18.58	$0.67	$32.67
Motor Vehicle Taxes	$2.20	$15.52	$0.39	$18.11
Tolls	–	$2.76	$0.68	$3.44
Total	$15.62	$36.86	$1.74	$54.22

[1] 1988 Revenue Data

Exhibit 2-6
Revenue from User Charges Used for Highways – 1989
($ in billions)

	Federal	State	Local [1]	Total
Motor Fuel Taxes	$11.92	$17.03	$0.54	$29.49
Motor Vehicle Taxes	$2.20	$9.32	$0.32	$11.84
Tolls	–	$2.50	$0.51	$3.01
Total	$14.12	$28.85	$1.37	$44.34

[1] 1989 Local Estimate from HF-10

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[1] Tax is 14.1 cents effective December 1, 1990.

[2] The weighted average State gasoline tax rate as of January 1991 was 15.76 cents per gallon.

[3] Tax is 20.1 cents effective December 1, 1990.

Exhibit 2-7
State Tax Rates on Motor Fuel – 1989[1]
(cents per gallon)

State	Gasoline		Diesel		L.P.G.		Gasohol		
	Rate	Date of Change	Rate	Date of Change	Rate	Date of Change	Rate	Date of Change	Exemption
Alabama	13 [2]		14 [2]		12 [3]		13 [2/4]	1-1	0
Alaska	8		8		0		0		8
Arizona	17		17		17		17		0
Arkansas	13.5		12.5		11.5		13.5		0
California	9		9		6		9 [5]		0
Colorado	18		20.5		20.5		18		0
	20	8/1	20.5		20.5		20	8/1	0
Connecticut[5]	20		20		20		19		1
Delaware	16		16		16		16		0
Dist. of Col.	15.5		15.5		15.5		15.5		0
	18	7/1	18	7/1	18	7/1	18	7/1	0
Florida	9.7[7]		9.7		4		9.7[7]		0
Georgia	7.5		7.5		7.5		7.5		0
Hawaii	11 [8]		11		7		11 [9]		0
Idaho	18		18		18		14		4
Illinois	13		15.5		13		13		0
	16	8/1	18.5	8/1	16	8/1	16	8/1	0
Indiana	15		16 [10]		16		15		0
Iowa	20	1/1	22.5	1/1	20	1/1	19	1/1	1
Kansas[11]	11		13		10		11		0
	15	7/1	17	7/1	14	7/1	15	7/1	0
Kentucky[11][12]	15		12		15		15		0
Louisiana	16		16		16		16 [13]		0
Maine	16		19		19		14		2
	17	4/1	20	4/1	20	4/1	15	4/1	2
Maryland	18.5		18.5		18.5		18.5		0
Massachusetts[11]	11		11		4.5		11		0
Michigan	15		15 [14]		15		15		0
Minnesota[11]	20		20		20		18		2
Mississippi	18	1/1	18	1/1	17	1/1	18	1/1	0
Missouri	11		11		11		11 [13]		0
Montana	20		20		0		20		0
Nebraska[11]	18.2	1/1	18.2	1/1	18.2	1/1	15.2	1/1	3
	18.5	4/1	18.5	4/1	18.5	4/1	15.5	4/1	3
	22.3	7/1	22.3	7/1	22.3	7/1	19.3	7/1	3
	22.0	10/1	22.0	10/1	22.0	10/1	19.0	10/1	3
Nevada	18		20		11.72		18		0
New Hampshire	14		14 [15]		14		14		0

Exhibit 2-7
State Tax Rates on Motor Fuel – 1989[1]
(cents per gallon)
(cont.)

State	Gasoline		Diesel		L.P.G.		Gasohol		
	Rate	Date of Change	Rate	Date of Change	Rate	Date of Change	Rate	Date of Change	Exemption
New Jersey	10.5		13.5		5.25		4.5[4]		6
New Mexico	14		16		16		6[4]		8
	16	7/1	16		16		8	7/1	8
New York[6]	8		10		8		8		0
North Carolina[11]	15.7		15.7		15.7		15.7		0
	20.9	8/1	20.9	8/1	20.9	8/1	20.9	8/1	0
North Dakota	17		17[16]		17		13		4
	17		17[16]		17		17	7/1	0
Ohio[11]	14.8		14.8		14.8		14.8[13]		0
	18	7/15	18	7/15	18	7/15	18[13]	7/15	0
Oklahoma	16[17]		13		16		16[17]		0
Oregon	16	1/1	16[18]	1/1	16[18]	1.1	16	1/1	0
Pennsylvania[6]	12		12[10]		12		12		0
Rhode Island[11]	15		15		15		15		0
	20	7/1	20	7/1	20	7/1	20	7/1	0
South Carolina	16	1/1	16	1/1	16	1/1	10	1/1	6
South Dakota	18		18		16		16		2
Tennessee	17[19]		15		13		13[19]		4
	20[19]	4/1	16	4/1	14	4/1	16[19]	4/1	4
	21[19]	7/1	16		14		17[19]	7/1	4
Texas	15		15		15[3]		11[20]		4
	15		15		15[3]		15[20]	2/1	0
Utah	19		19		19		19		0
Vermont	13		14		0		13		0
	14	4/1	15	4/1	0		14	4/1	0
	15	7/1	16	7/1	0		15	7/1	0
Virginia[12]	17.5		16		16		17.5[13]		0
	17.7	7/1	16.2	7/1	16.2	7/1	17.7[13]	7/1	0
Washington	18		18		0		16.2[4]		1.8
West Virginia	10.5		10.5		10.5		10.5		0
	15.5	4/1	15.5	4/1	15.5	4/1	15.5	4/1	0
Wisconsin[11]	20.9		20.9		20.9		20.9		0
	20.8	4/1	20.8	4/1	20.8	4/1	20.8	4/1	0
Wyoming	8		8		0		8		0
	9	7/1	9	7/1	0		5	7/1	4

Exhibit 2-7
State Tax Rates on Motor Fuel – 1989[1]
(cents per gallon)
(cont.)

California	4.75	Applies to sales price including federal and state motor-fuel taxes. Local governments assess an additional 1.25% except in bay area where the rate is 1.75%.
Georgia	3	A second motor-fuel tax applies to sales price including federal motor-fuel tax.
Hawaii	4	Applies to sales price excluding federal and state motor-fuel taxes, but gasohol is exempted.
Illinois	5	Applies to sales price excluding federal and state motor-fuel taxes. Most local governments assess an additional 1% tax. Gasohol is taxed at 2% from June 1, 1986 through December 31, 1992, and at 5% thereafter.
Indiana	5	Applies to sales price excluding federal and state motor-fuel taxes.
Kansas	4	State sales tax and 1.5% maximum of city and county sales taxes are paid on aviation fuel which is not subject to refund.
Michigan	4	Applies to sales price including federal motor-fuel tax except for those who have a sales tax exemption certificate.
New York	4	Applies to sales price including federal motor-fuel tax. Local governments assess additional tax varying from 1% to 4%.
Virginia	2	Applies to retail sales within a county or city which is a member of any transportation district in which a heavy rail commuter mass transportation system or a bus commuter mass transportation system is owned and operated by a transportation agency.
West Virginia	5	Applies to the average wholesale price as determined annually by the tax commissioner. However, the wholesale price cannot be set at less than 97 cents per gallon.

[1] Rates in effect as of December 31, 1989.

[2] Includes 2 cents per gallon inspection fee.

[3] Owners of vehicles registered in the state pay an annual decal fee in lieu of a gallonage tax.

[4] Exemption from state motor-fuel tax provided alcohol was made in the state from agricultural commodities produced within the state. In New Jersey, the alcohol must be grain-derived ethyl alcohol produced within the state.

[5] Excise tax on alcohol fuels (ethanol or methanol) containing not more than 15% gasoline or diesel fuel is one-half the rate of the use fuel tax from January 1, 1982 until January 1, 1994.

[6] A "gross receipts tax" is assessed in Connecticut (2%), New York (2.75%), and Pennsylvania (6%).

[7] Rate consists of a fixed rate of 4 cents per gallon plus a 5 percent sales tax applied to the average retail price of motor fuel established annually, but the tax cannot go below 5.7 cents per gallon.

[8] County tax of 4 to 6.5 cents per gallon is also added.

[9] County tax of 3.5 cents per gallon is also added but exempted from sales tax.

[10] There is an additional 11 cents per gallon tax on diesel fuel for motor carriers in Indiana and an additional 6 cents per gallon tax on diesel fuel for motor carriers in Pennsylvania.

[11] "Variable Tax." Rates are determined at various times of the year.

[12] A 2% surtax is imposed on gasoline and 4.7% on special fuels for any vehicle with 3 or more axles in Kentucky. An additional 2 cents per gallon surtax on vehicles with a combined licensed weight in excess of 59,999 pounds is imposed. Motor fuel used by motor carriers is taxed at 19.5 cents per gallon in Virginia.

[13] Louisiana has a producer's incentive credit of $1.40 per gallon of ethanol. Missouri has a producer's incentive credit of 20 cents per gallon of ethanol. In Ohio, the dealer is refunded 20 cents per gallon of each qualified fuel (ethanol and methanol) that is blended with unleaded gasoline. Virginia has a producer's incentive credit of 60 cents per gallon of ethanol, not to exceed $6.5 million in any fiscal year.

[14] There is a 6 cents per gallon discount if diesel fuel is delivered into the fuel supply tank of a commercial vehicle which is licensed (decal) at the rate of $92 for a resident vehicle and $25 for a nonresident vehicle.

[15] A $20.00 decal is required for all diesel vehicles.

[16] Diesel fuel blended with recovered oil or agriculturally derived alcohol is taxed at 13 cents per gallon.

[17] Includes inspection fee of 0.08 cents per gallon.

[18] Taxes are paid by users for vehicles not under the jurisdiction of public utility commissioner. Vehicles under jurisdiction of public utility commissioner and paying motor-carrier fees are exempt from payment of the motor-fuel tax.

[19] Includes 1 cent fee per gallon inspection fee.

[20] Exemption for ethanol produced in state is a variable rate with a maximum of 4 cents per gallon. The variable rate is set quarterly to limit the total yearly exemption to $10,850,000.

Source: *Highway Statistics*, 1989, Table MF-12IT

Total motor fuel tax revenue used for highways was $29.5 billion in 1989, 40 percent of revenues. Federal levies were $11.9 billion, States $17.0 billion and local governments $.5 billion.

Motor Vehicles Taxes and Fees

This category includes an assortment of taxes and fees on motor vehicles and users. The following is a list of most of these revenue raising instruments:

- Registration fees
- Driver license fees
- Weight-distance taxes
- Motor carrier taxes
- Dealer licenses
- Certificates of title
- Plate fees or wheel taxes
- Sales taxes that apply specifically to motor vehicles
- Personal property taxes levied only on motor vehicles

Revenue from these sources used for highways totaled $11.8 billion in 1989, 16 percent of the total. Federal revenue from motor vehicles was $2.2; State revenue $9.3; and Local revenue $0.3 billion.

Tolls

States and local governments operate toll systems of all sizes, from minor crossings to statewide and regional toll transportation systems. At present, 29 States operate 37 toll roads and 44 toll bridges. In addition, 20 county and 27 municipal toll facilities, mainly bridges, exist nationwide.

Toll facilities provided $3.01 billion for highway financing in 1989. State toll facilities generated $2.50 billion and local toll facilities $0.51 billion.

Total Revenues from User Charges

Total revenues used for highways from user charges in 1989 (net of cost of collection) were $44.3 billion or 60% of all revenues used to finance highways. This is the same share of highway investments financed from user charges as in 1987. Reliance on user charges as a source of revenues reached a peak of 73 percent in 1964.

Non-Highway Based Financing

Non-highway based financing includes all revenue instruments that have little or no direct connection with the highway user tax base. In some cases, these imposts provide dedicated revenues for highways. However, most of these revenues are placed in the general fund and are subsequently apportioned for highways. The most frequently used revenue instruments in this category include general taxes on property and sales, and the income tax.

Local governments rely most heavily on non-highway based revenue sources to finance their highway programs as seen Exhibit 2-8.

Exhibit 2-8
Revenue from Non-Highway Based Sources Used for Highways - 1989
($ in billions)

Federal	State	Local	Total
0.99	1.52	8.95	11.46

While most of these revenue sources have no specific connection with the highway tax base, some, including general sales taxes that apply to motor fuel and vehicles, and personal property taxes that apply to a range of personal property including motor vehicles, are sometimes considered to be highway-based revenues. In Exhibit 2-4, any revenues that cannot be attributed to the other revenue categories are assumed to come from this source.

Benefit Charges Including Private Cost Sharing

Benefit charges include charges on activities, usually related to land use, that derive a benefit from highways. The following is a partial list of revenue raising instruments considered to be benefit charges:

- Real property taxes imposed by Single Function Highway Districts
- Assessments levied for construction and maintenance of roads and streets or for local debt service
- Impact fees
- Severance fees imposed to compensate for the impact of the extraction activity on highways

The term "benefit charge" implies a requirement to pay. While not specifically a "benefit charge," voluntary contributions from private property owners of land for right-of-way or cash against the cost of a new public facility, are also considered to be "benefit charge" revenue. Private property owner contributions are variously referred to as donations, negotiated contributions, developer agreements, and exactions.

The first three revenue raising instruments listed are a form of institutionalized cost-sharing. They are the means by which local governments (often with required State support) raise funds for specific transportation improvements through systematic and simultaneous cost-sharing with multiple private parties whose properties are directly served by a transportation improvement.

In contrast to the ad hoc and usually extremely localized contributions or exaction, these methods require the establishment of a systematic and equitable assessment process within a specific area (district). The specific group of property owners who will benefit directly through transportation improvement-induced changes in economic activity (including property values) is assessed.

Three methods are typically in use in the United States:

- Benefit assessment districts (periodic earmarked fees for transportation applying to new development in the highway environment).
- Tax increment financing assessing property value increases applying to all property owners in a transportation-affected area.
- Traffic impact fees required of property developers based on specific development attributes applied as a condition of development.

Funds from direct beneficiaries are thus generated to help pay for public projects that would otherwise place a burden on a local jurisdiction's general tax base.

Funding for projects built by the private sector and turned over to a governmental jurisdiction after completion with no effect on either the jurisdiction's revenues or expenditures for highways are not included. Funding for these types of projects is considered private sector financing and is separately discussed.

These revenue instruments are used primarily at the local level and are difficult to quantify. Based on highway statistics data collected from the states, at least $4.5 billion was raised from property taxes and assessments and $2.5 billion was raised from other taxes and fees. See Exhibit 2-9.

Investments and Miscellaneous Fees

By investing highway funds until needed, many highway agencies are able to realize interest income or profit on the purchase and sale of securities. Other miscellaneous income includes rentals, and permit fees. Revenues from this source used for highways were $5.78 billion in 1989 or 8 percent of total revenues, also the same share of total revenue as in 1987. This revenue source is used by all levels of government as seen in Exhibit 2-10.

Exhibit 2-9
Revenues from Benefit Charges Used for Highways – 1989
($ in billions)

	Federal	State	Local	Total
Property Taxes and Assessments	–	–	4.54	4.54
Other Taxes and Fees	0.07	1.37	1.01	2.45
Total	0.07	1.37	5.55	6.99

Exhibit 2-10

Revenue from Investment Income and Miscellaneous Receipts Used for Highways – 1989

($ in billions)

Federal	State	Local	Total
1.36	2.09	2.33	5.78

Bond Issues

Proceeds from bond issues used for highways were $5.0 billion in 1989. State agencies raised $3.1 billion and local governments, $2.0 billion (see Exhibit 2-11). Revenue from this source was 7 percent of the $73.6 billion total allocated to highways in 1989, the same as in 1987.

Highway Based Revenues Compared with Non-Highway Based Revenues Used for Highways

Highway based revenue sources include most bond issues, investments and miscellaneous fees, user charges, and benefit charges. Together they provided approximately $62.16 billion (84 percent) of the revenues used to finance highways in 1989. If revenue from general taxes on property and sales imposed on motor vehicles and motor fuel were included, the share of revenues used for highways derived from highway based revenue sources would be higher.

Non-highway based revenue sources provided approximately $11.47 billion (16 percent).

Exhibit 2-11

Revenue from Bond Issues Used for Highways – 1989

($ in billions)

Federal	State	Local	Total
–	3.06	2.00	5.06

Revenue Trends for Selected Highway User Revenue Sources

This section contains an analysis of trends in revenue generated by various user charges from 1960 through 1989. In addition to overall trends, trends in revenue per vehicle mile of travel (VMT) and per vehicle are considered for motor fuel tax revenue and motor vehicle revenue, respectively.

Federal Motor Fuel Tax Revenue Trends

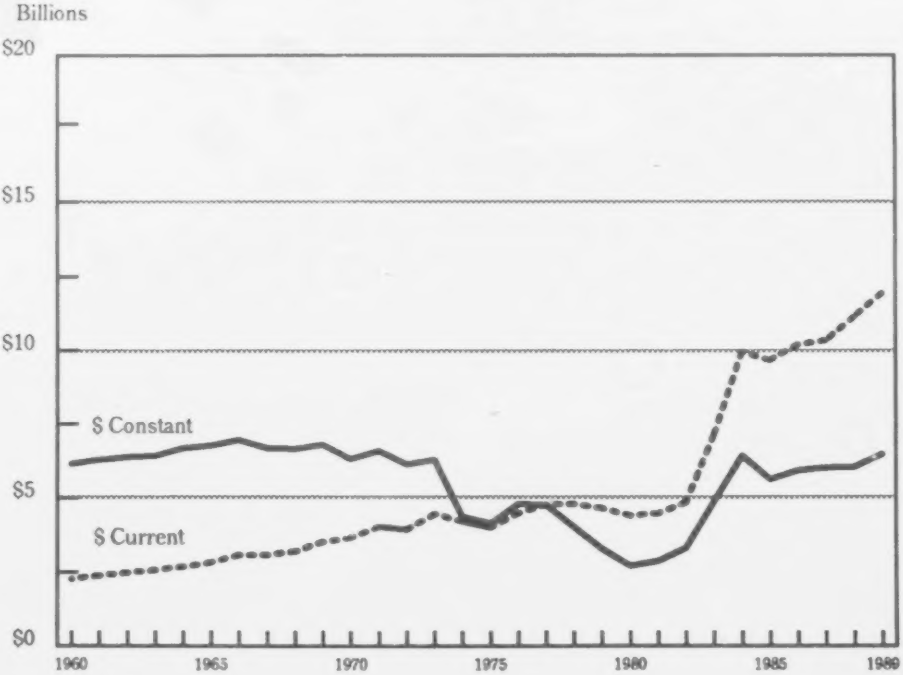
In 1989, Federal motor fuel taxes generated $13.5 billion in revenues for the Highway Trust Fund; $11.9 billion of this revenue was spent on highway improvements. Since 1960, revenues from Federal motor fuel tax revenues used for highways have increased by $9.6 billion in current dollars and $0.3 billion in constant dollars (see Exhibit 2-12). Constant dollar revenues from this revenue source reached a peak of $6.9 billion in 1966. The low point in constant dollars for revenue from this source, $2.7 billion, was reached in 1980.

Federal motor fuel tax revenue used for highways in constant dollars was $8.56 per 1,000 vehicle miles of travel (VMT) in 1960 and $3.74 in 1989. As with total revenues from this source, revenues per 1,000 VMT reached a low of $1.77 in 1980. However, revenues per 1,000 VMT reached a peak of $8.56 in 1960 rather than in 1966.

State Motor Fuel Tax Revenue Trends

In 1960, State motor-fuel taxes raised $3.3 billion dollars for highway use. By 1989 the yield was $17.0 billion, or 5.2 times greater. The gain in revenue resulted from the compounding effects of doubling motor-fuel consumption (2.3 times) and doubling State tax rates (2.4 times). However, inflation in highway construction has dramatically reduced the productivity of the State motor fuel tax dollar resulting in a constant dollar yield in 1989 of $9.2 billion, only $0.4 billion dollars more than the 1960 yield.

Exhibit 2-12
Federal Motor Fuel Tax Revenue Used for Highways



As shown in Exhibit 2-13, current revenue from State motor-fuel taxes used for highways has increased almost annually since 1960. The rate of increase, however, slowed from 1973 through 1980. When expressed in constant dollars, revenues from this source actually declined during this period. From 1980 on, real revenue has again increased almost annually as it did from 1960 through 1973 because of lower inflation and the increase in State motor fuel tax rates.

During this same period, however, State motor fuel revenue has declined when measured in constant dollars per vehicle-mile of travel. Revenue in constant dollars per 1,000 VMT dropped from $12.25 in 1960 to $4.39 in 1989 - a decline of nearly two-thirds. This decline is caused, in part, by the greater efficiency of today's motor vehicles. Average miles-per-gallon (MPG) for autos was over 20 in 1989 whereas the comparable rate was 14 in 1960. As with Federal motor fuel taxes used for highways, revenue from this source per 1,000 VMT reached a constant dollar low of $3.58 in 1980.

Federal Motor Vehicle Tax Revenue Trends

Total motor vehicles registered in the Nation reached 192 million in 1989. Revenues used for highways were $2.2 billion in 1989 compared to $0.6 billion in 1960 (see Exhibit 2-14). Current dollar revenues reached a peak of $2.4 billion in 1979.

Exhibit 2-13
State Motor Fuel Tax Revenue
Used for Highways

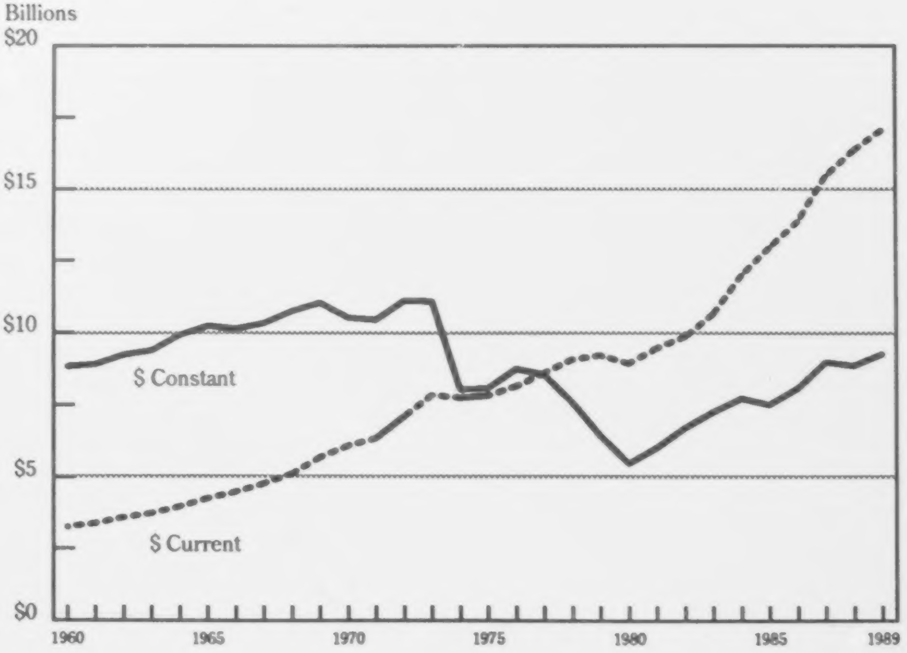
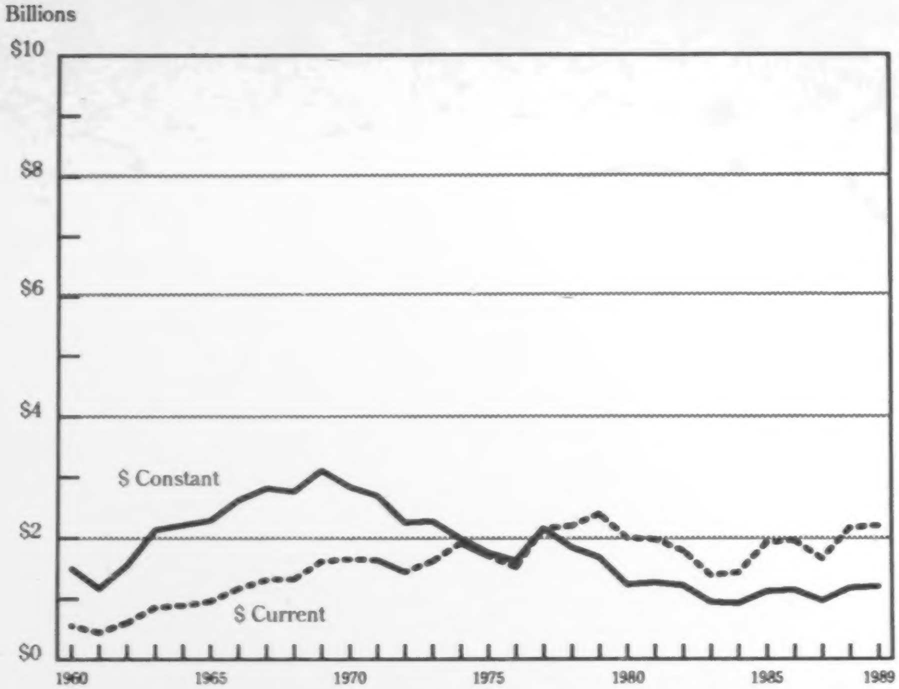


Exhibit 2-14
Federal Motor Vehicle Tax Revenue Used for Highways



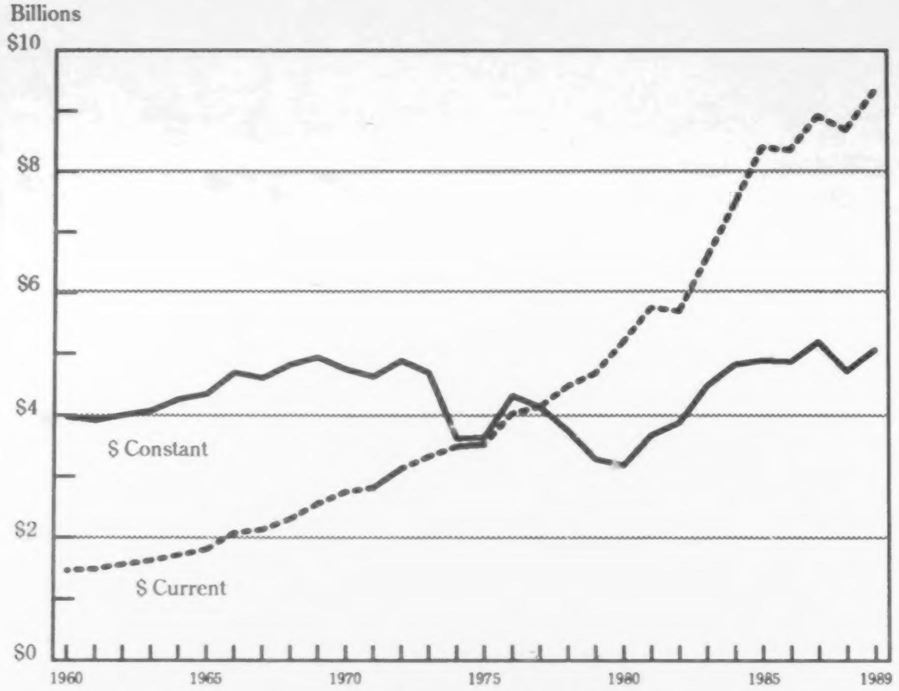
In constant dollars, revenues from this source have declined since 1960 with the low of $0.9 billion being reached in 1983 and 1984. The constant dollar revenue peak of $3.1 billion occurred in 1969.

Federal motor vehicle tax revenue per vehicle has increased from $7.40 in 1960 to $11.48 in 1989. Per vehicle current dollar revenue reached a peak of $15.27 in 1979. In constant dollars, however, per vehicle revenue from this source has declined from $20.00 in 1960 to $6.23 in 1989. The constant dollar revenue peak per vehicle of $28.95 was reached in 1969 and the low of $5.36 in 1984.

State Motor Vehicle Tax Revenue Trends

Taxes on the motor vehicle tax base produced $15.5 billion in total revenue for the States in 1989; $9.3 billion was used for highways. Current dollar revenue used for highways raised in 1989 was over six times that of 1960, resulting from the combination of an increased number of vehicles (192 versus 73 million) and an increased average fee per vehicle. See Exhibit 2-15. Together these two factors were able to overcome the effect of inflation in highway construction resulting in a real increase in revenue from this source of approximately $1 billion from 1960 through 1989. However, constant dollar revenues actually

Exhibit 2-15
State Motor Vehicle Tax Revenue Used for Highways

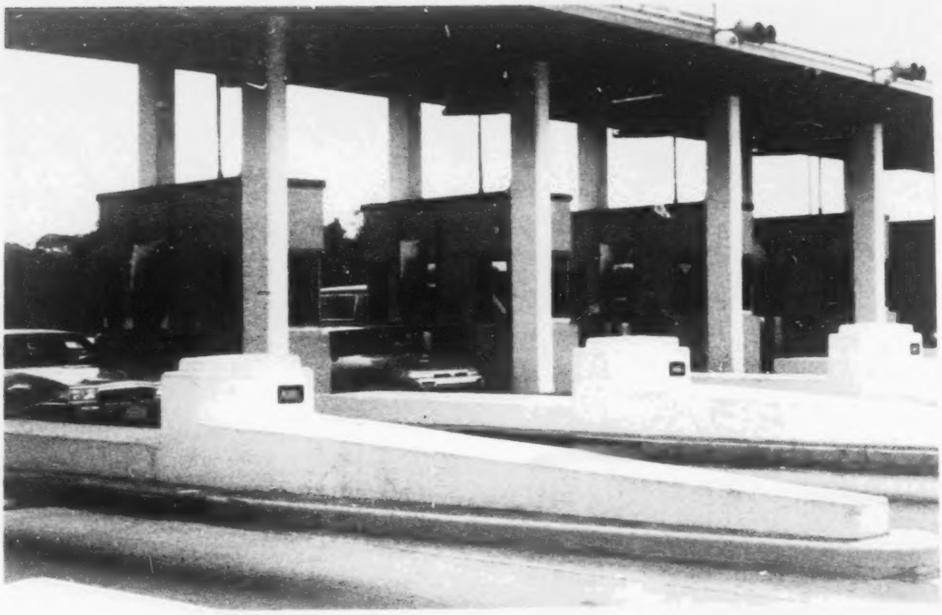


declined below the $4.0 billion dollar level reached in 1960 for several years during the 1970's and early 1980's and reached a low of $3.2 billion in 1980.

While there has been a real increase in total revenue used for highways from this source since 1960, on a per vehicle basis constant dollar revenue has declined from $53.20 per vehicle in 1960 to $26.39 in 1989. Constant dollar revenue reached a low of $19.74 per vehicle in 1980.

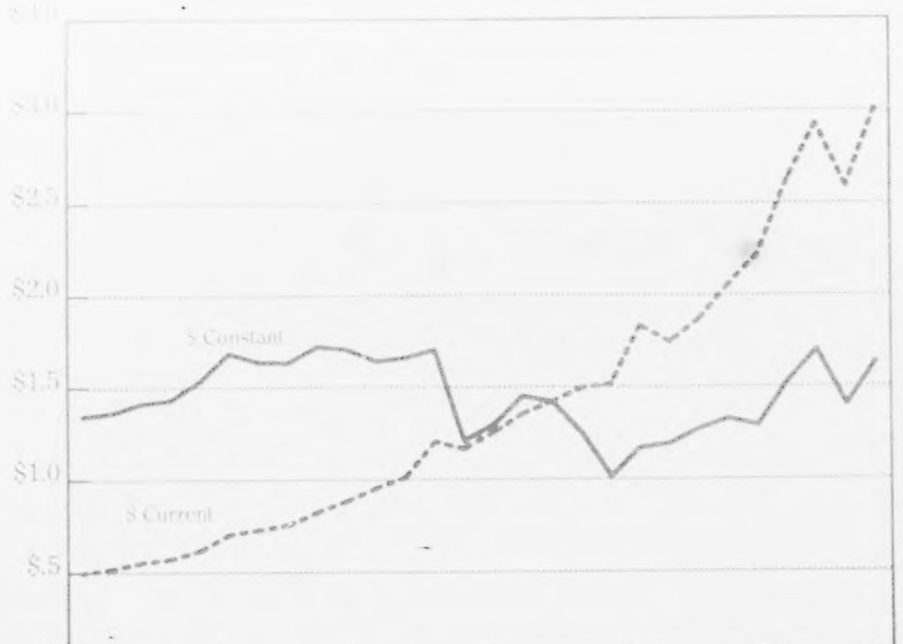
Toll Revenue Trends

In 1989, State and local revenue used for highways from road and crossing tolls was $3.0 billion in current dollars and $1.6 billion in constant dollars. Since 1960, toll revenues have increased 22 percent in constant dollars, however, this has not been a steady increase. As shown in Exhibit 2-16, during the period from 1960 through 1972 constant dollar toll revenues generally increased, reaching a high of $1.8 billion in 1972. From 1975 through 1980, revenues declined. Since 1980, constant dollar revenues from tolls have increased 61 percent from $1.0 billion to $1.6 billion but remain less than constant dollar revenues in 1972. Toll revenues as a share of total revenues for financing highways was 4 percent in 1989, the same as in 1960.



Toll facilities provided $3.0 billion for highway investment in 1989

Exhibit 2-16
Toll Revenue Used for Highways



User Charge Revenues Trends

Total revenues from user charges in current dollars have increased from $8.4 billion in 1960 to $54.2 billion in 1989 and in constant dollars from $22.8 billion in 1960 to $29.4 billion in 1989. Constant dollar revenues from this source reached a peak of $29.4 billion in 1969 (see Exhibit 2-17). A gradual decline in revenues accelerated in the early 1970's when revenue dropped approximately 25 percent in one year from 1973 to 1974. The low point in constant dollar revenues, $15.8 billion was reached in 1980.

Annual constant dollar revenues per vehicle from user charges was $306 in 1960 and $154 in 1989. Annual per vehicle user charge revenues peaked at $308 in 1964 and reached a low of $103 in 1981.

However, not all revenue raised from highway user charges are used for highways. User charge revenues used for highways in current dollars were $8.1 billion in 1960 and $44.3 billion in 1989. Comparable revenues in constant dollars were $22.0 billion in 1960 and $24.7 billion in 1989 (see Exhibit 2-18).

Annual constant dollar revenues per vehicle used for highways from user charges was $295 in 1960, the high for the period, and $125 in 1989. Annual per vehicle user charge revenues used for highways reached a low of $85 in 1980.

In 1960, 3.5 percent of constant dollar revenues from user charges were not spent on highways. By 1989, the percent of revenues being diverted from use for highways had increased to 16 percent.

Highway Noncapital Expenditures and Trends

This section presents a brief overview of noncapital highway expenditures from 1960 through 1989. Noncapital highway expenditures include maintenance and operations of highways, administration, highway law enforcement, safety, and debt service on highway bonds and notes. The noncapital highway bill for the public sector was $38 billion for 1989, or 53 percent of all highway expenditures. (Exhibit 2-19)

Maintenance and Traffic Services

The most expensive noncapital highway activity is roadway maintenance and operations. Maintenance costs include routine and regular expenditures required to keep highways in usable condition, such as patching repairs, bridge painting, and other maintenance of condition costs; and traffic service costs, such as snow and ice removal, pavement markings, signs, signals, litter cleaning, and toll collection expenses. Expenditures for maintenance and traffic services are not eligible for Federal-aid.

A total of $19.7 billion was spent by State, county, and municipal governments in 1989 to keep roads and streets in serviceable condition. The 1989 maintenance and operation spending was 7.5 times that of 1960 and still

Exhibit 2-17
Total Revenue from User Charges

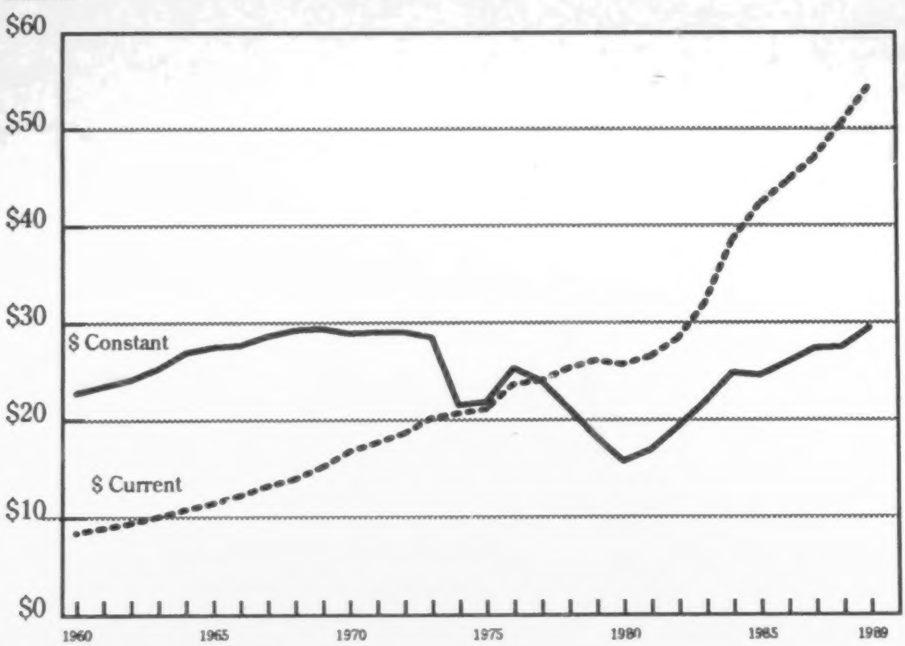
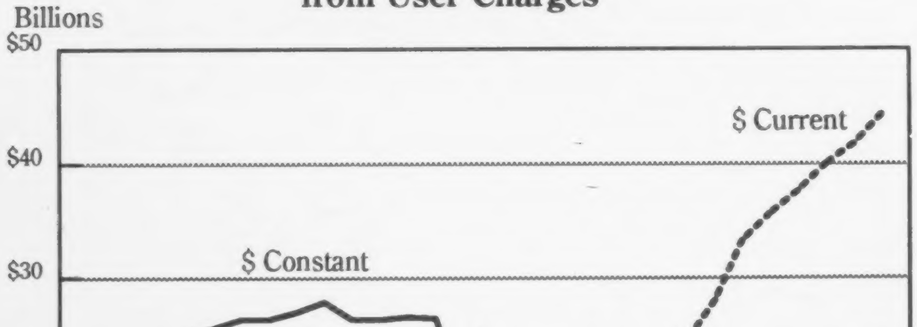


Exhibit 2-18
Total Revenues Used for Highways from User Charges



accounts for about one dollar in four of all highway costs (1989 = 28 percent, 1960 = 25 percent).

Administration and Safety

Both highway administration and highway safety expenditures have recorded substantial growth over the last three decades. Administration, including highway planning and research, for 1989 is over 11 times that of 1960, and its share of all disbursements is up from 4.6 percent to 7.5 percent. Highway safety expenditures have grown the most, a 20-fold increase since 1960. Highway safety now commands 9 percent of all spending compared to 3 percent for 1960.

Debt Service

Highway debt service cost is the only noncapital highway cost showing a reduced share of total outlays. The sum of interest on debt and the annual redemption of bonds accounted for 9.5 percent of all costs in 1960, but debt service required 8.9 percent of all disbursements in 1989.

Exhibit 2-19
Disbursements for Highways by Functions for Selected Years, All Units of Government (in millions of dollars)

Year	Capital Outlay	Maintenance and Operations	Administration, etc.	Highway Patrol and Safety	Interest on Debt	Subtotal Current Disbursements	Debt Retirement	Total
1960	6,290	2,640	483	327	420	10,160	601	10,761
1964	8,252	3,060	684	474	515	12,985	752	13,737
1968	10,346	4,003	1,017	940	606	16,912	1,071	17,983
1972	12,275	5,443	1,600	1,671	950	21,939	1,270	23,209
1974	13,102	6,573	1,857	2,061	1,079	24,672	1,445	26,117
1976	13,927	7,735	2,209	2,633	1,234	27,738	1,567	29,305
1978	14,938	9,785	2,590	3,160	1,368	31,841	1,593	33,434
1980	20,337	11,445	3,022	3,824	1,456	40,084	1,711	41,795
1981	19,734	12,165	3,439	3,884	1,202	40,424	2,464	42,888
1982	19,052	13,319	3,152	4,068	1,690	41,281	2,046	43,327
1983	20,224	14,240	3,347	4,309	1,872	43,992	2,172	46,164
1984	23,123	15,008	3,604	4,937	1,641	48,313	2,411	50,724
1985	26,647	16,589	4,174	5,241	2,148	54,799	2,737	57,536
1986	29,179	17,643	4,677	5,549	2,505	59,553	2,793	62,347
1987	30,674	18,152	4,973	5,962	2,788	62,549	2,685	65,234
1988	32,883	19,110	4,961	6,108	2,773	65,835	2,755	68,590
1989	33,274	19,679	5,380	6,453	2,871	67,657	3,478	71,135

Source: *Highway Statistics*, HF-12, various years; and HF-10, October 1990.

Highway Capital Expenditures and Trends

This section presents an overview of public sector highway capital expenditures and trends. Highway capital expenditures are those outlays associated with highway improvements, including land acquisition and other right-of-way costs; preliminary and construction engineering; new construction, reconstruction, resurfacing, rehabilitation, and restoration costs of roadways and structures; and installation of traffic service facilities such as guard rails, fencing, signs, and signals. All of these types of expenditures are eligible for Federal-aid.

All governments spent over $33 billion on capital outlay in 1989 (Exhibit 2-19). In 1960, capital expenditures accounted for 58 percent of all highway spending; for 1989 the share was 47 percent. For every 1,000 VMT, $15.80 was spent on highway capital improvements.

Capital Expenditures for Capacity and Preservation

Capital spending on highways can be differentiated on the basis of whether it adds additional capacity or preserves existing physical conditions. Capacity improvements include reconstruction with added lanes and wider lanes, and major widening as well as new construction on new right-of-way. Preservation improvements include pavement reconstruction, resurfacing with shoulder or alignment improvements, and resurfacing. As shown in Exhibit 2-20, capacity improvements account for 53 percent of spending on non-local roads; preservation improvements account for 47 percent.

Highway Capital Expenditure Trends

Highway capital outlay by all units of government has grown from $6.3 billion in 1960 to $33.3 billion for 1989 (see Exhibit 2-21). In constant dollars, today's spending is comparable to that of the 1960's. The constant dollar low point in capital spending for highways during this period was the $12.5 billion dollars spent in 1980. Since 1980, capital outlay increased in constant dollars until 1987, before plateauing in the last few years.

Total highway capital outlay per mile of travel has almost doubled since 1960 in current dollars but is down over 60 percent in constant dollars (See Exhibit 2-22). Inflation increased highway costs nearly 5-fold from 1960 to 1989 and real highway spending dropped from over $23 per thousand miles traveled in 1960 to $8.58 per thousand miles traveled in 1989. Since 1980, relative price stability along with a 64-percent increase in current highway capital spending resulted in a modest growth in real spending per unit of travel. Still, today's real spending is less than half the 1960 level.

Capital Financing by Level of Government

This section presents the sources of funding for capital financing by governmental jurisdiction. By law, Federal-aid program funds have been legislatively restricted or "earmarked" for capital improvements only. However, while the amount spent by State and local governments for capital improvements is known, the source of these funds cannot be accurately determined since they are not necessarily "earmarked." The analysis in this section is based on the assumptions (1) that all Federal funds are spent on capital outlay and (2) that the rest of the funding for capital improvements comes from State and local revenues. There is no attempt made to differentiate between State and local revenue sources for capital improvements.

Federal Government

The Federal Government provided funds for 43 percent of the total highway capital outlay of $33 billion in 1989. With the exception of approximately $1 billion provided by other Federal agencies, all of these funds came from the Federal Highway Administration. The Federal share of highway capital outlay in 1989 is down from a high of 56 percent in 1980. After the 5 cent per gallon increase in the Federal gas tax took effect, the Federal share was 55 percent in 1985, but it has been dropping ever since. The current Federal share of 43 percent duplicates its 1970 level (See Exhibit 2-23).

State and Local

State and local governments supplied over half of all funds for highway capital improvements in 1989 as they did during the period from 1960 to 1975. The combined State/local share of capital outlay gradually declined during the late 1970's before leveling off at approximately 45 percent during the early 1980's. Since 1985, the State/local share of capital outlay has been increasing annually.

Exhibit 2-20
Spending by Major Improvement Categories on Non-Local Roads

	Percent
System Performance	
Pavement and safety improvements on arterials and collectors	24%
Bridge replacement/rehabilitation on arterials and collectors	16%
Operational improvements to arterials and collectors	6%
Capacity Improvements	
Capacity additions to arterials and collectors	25%
New highway/bridge construction arterials and collectors	28%
Total Capital Spending on Non-Local Roads	100%

Exhibit 2-21
Highway Capital Outlay All Units of Government

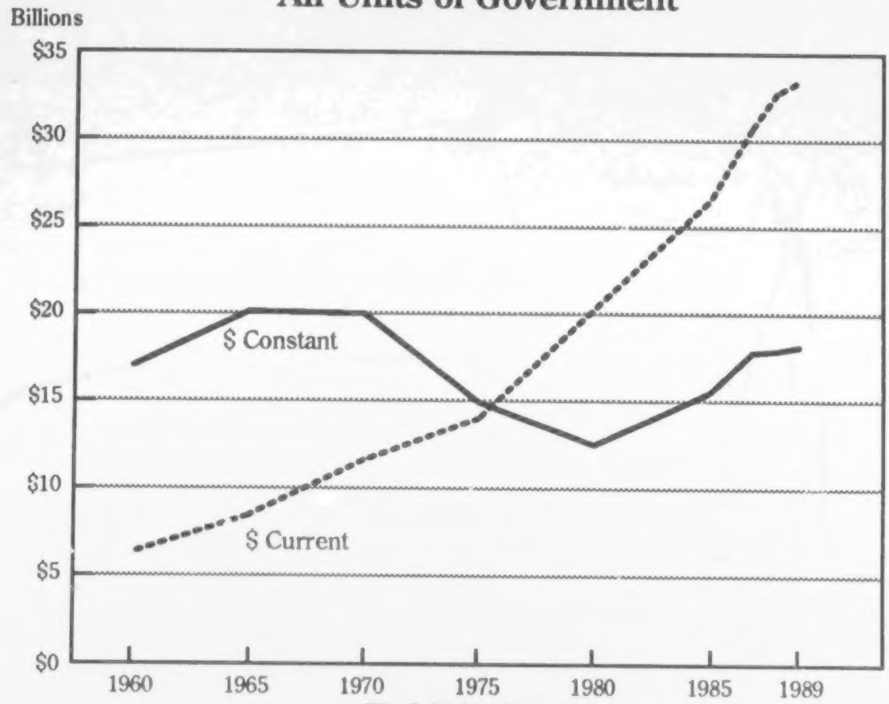
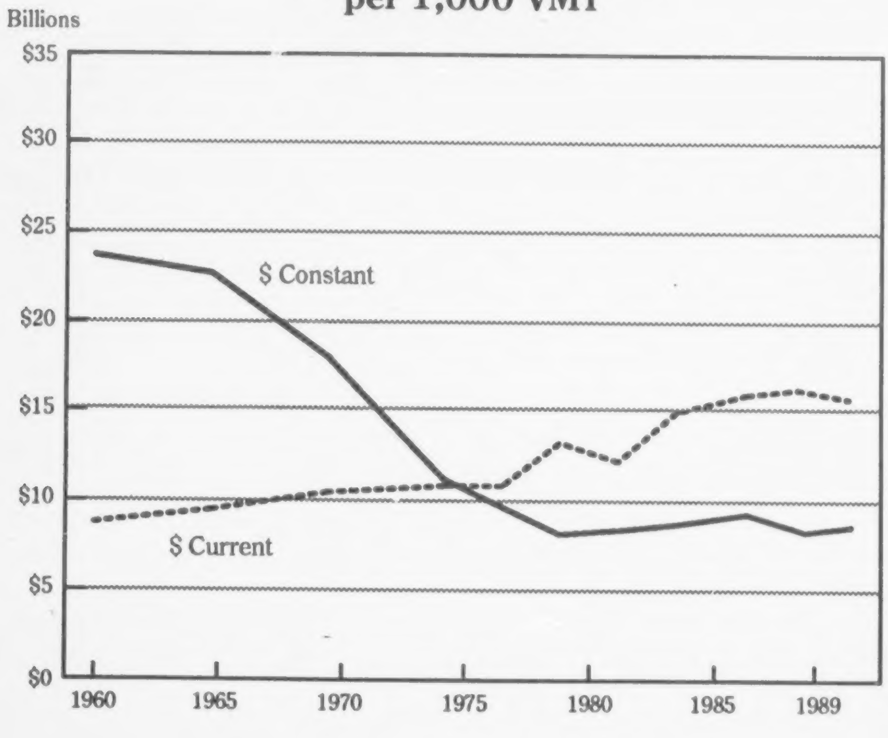


Exhibit 2-22
Highway Capital Outlay per 1,000 VMT



Highway Capital Outlay on Federal-Aid Systems

This section considers public sector capital outlay on the Federal-aid System. The Federal-aid System consists of those roadways that are eligible for Federal-aid (see Chapter 1). Total capital outlay on Federal-aid highway systems is estimated to account for $25 billion of the $33 billion expended for capital outlay in 1989 (See Exhibit 2-24). Based on State expenditure data only, capacity improvements account for 54 percent of these expenditures. This is comparable to the 53 percent spent on capacity improvements on all non-local roads. Highway capital outlay for each Federal-aid System is discussed in the following paragraphs.

Interstate System

The Federal-aid Interstate System (FAI) capital outlay amounted to $8.2 billion for 1989. As shown in Exhibit 2-24, expenditures on the rural Interstate were $2.5 billion or $13.08 per 1,000 VMT. Expenditures on the urban Interstate were $5.7 billion or $21.06 per 1,000 VMT.

The funding of the Interstate Highway System is largely a Federal-State activity with Federal funds dominating. In 1989, 79 percent of the funding for capital expenditures on the Interstate System came from the Federal Government (Exhibit 2-25). The remaining 21 percent came from the States. Of this, roughly half was spent to match Federal funding on projects in the Federal-aid participating program. The other half of State funding was spent on projects with no Federal involvement.

Interstate improvements are mainly for system preservation. Less than 30 percent of capital outlay on the Interstate is spent for new construction (see Exhibit 2-26).

Federal-Aid Primary System

The next system of national significance is the Federal-aid Primary system. Outlays from all sources on the Federal-aid Primary System (FAP) were $10.6 billion in 1989. On the rural Primary System, 1989 expenditures were $17.62 per 1,000 VMT; on the urban Primary System, expenditures were $18.76 per 1,000 VMT (see Exhibit 2-24).

The FAP system is almost totally located on highways under the jurisdiction of the States making the program essentially a Federal-State activity. In 1989, the Federal share of spending on the rural FAP was 44 percent and on the urban FAP was 54 percent (Exhibit 2-25). All of the remaining funding for the FAP came from State and local revenues.

New construction accounts for almost 30 percent of all capital expenditures on the overall FAP system (see Exhibit 2-27).

Exhibit 2-23
Federal Share of Funding for Highway Capital Outlay

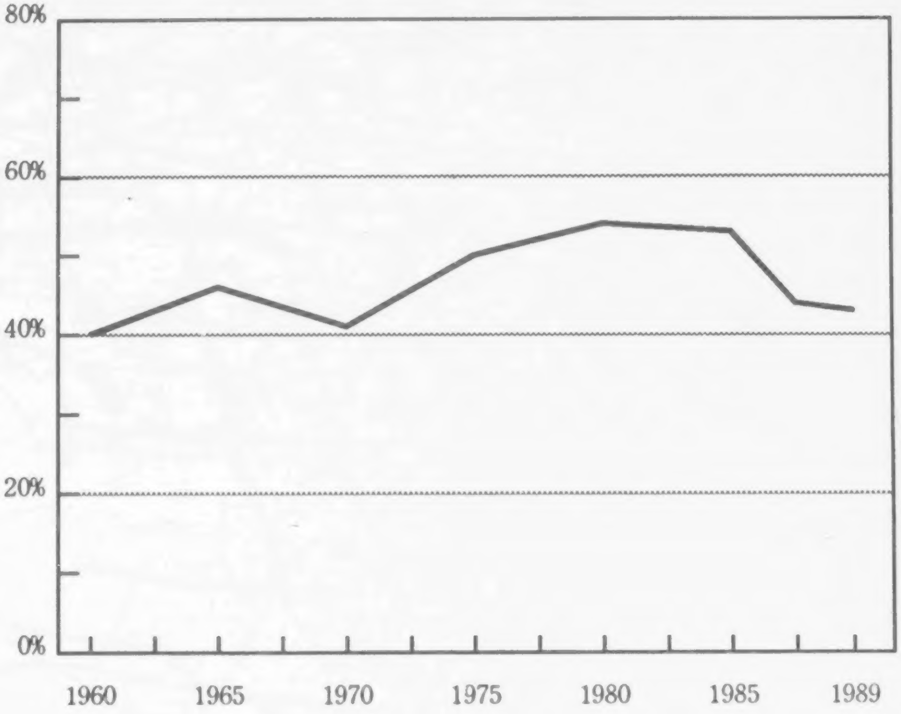


Exhibit 2-24
Total Highway Capital Outlay per 1,000 VMT for 1989

System	Capital Outlay ($ billions)	Travel (VMT)[1/] (billions)	Expenditures Per 1,000 VMT
Interstate – Rural	2.5	191.1	$13.08
Interstate – Urban	5.7	270.7	21.06
FA Primary – Rural	5.6	317.8	17.62
FA Primary – Urban	5.0	266.5	18.76
FA Urban	3.6	463.3	7.70
FA Secondary	2.7	179.3	15.06
Total Federal-Aid Systems	25.1	1,688.7	14.86
Non Federal-Aid Systems	8.2	418.3	19.60
All Systems	33.3	2,107.0	$15.80

[1/] Table VM-3, *Highway Statistics*, 1989.

Exhibit 2-25
Shares of Federal-Aid System Capital Outlay by Level of Government — 1989

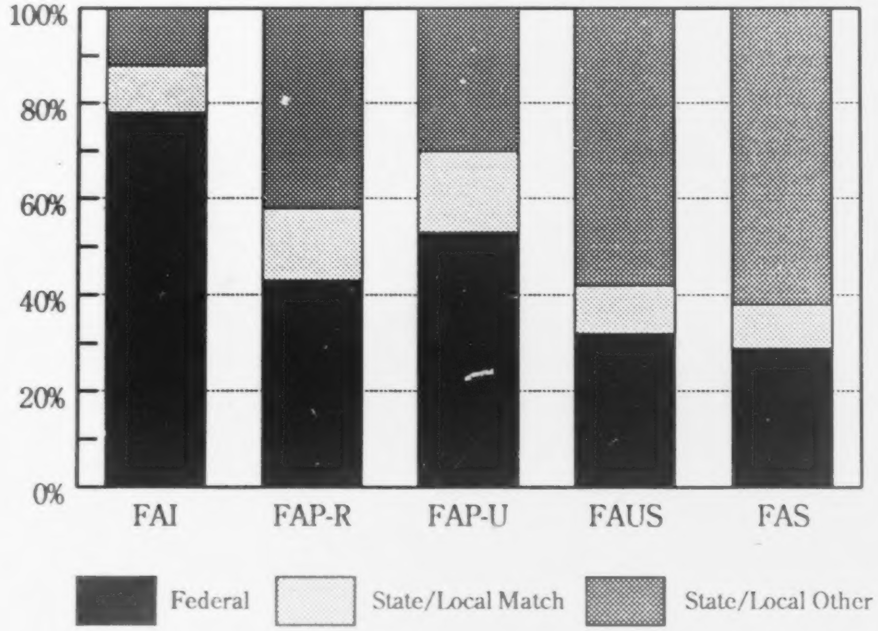


Exhibit 2-26
Distribution of Interstate Highway Capital Outlay by Improvement Type

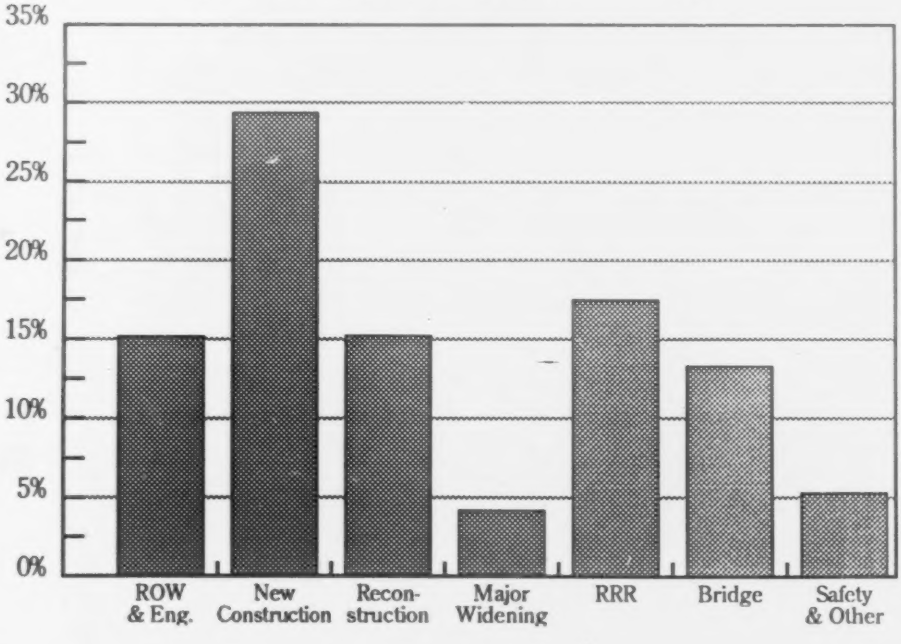
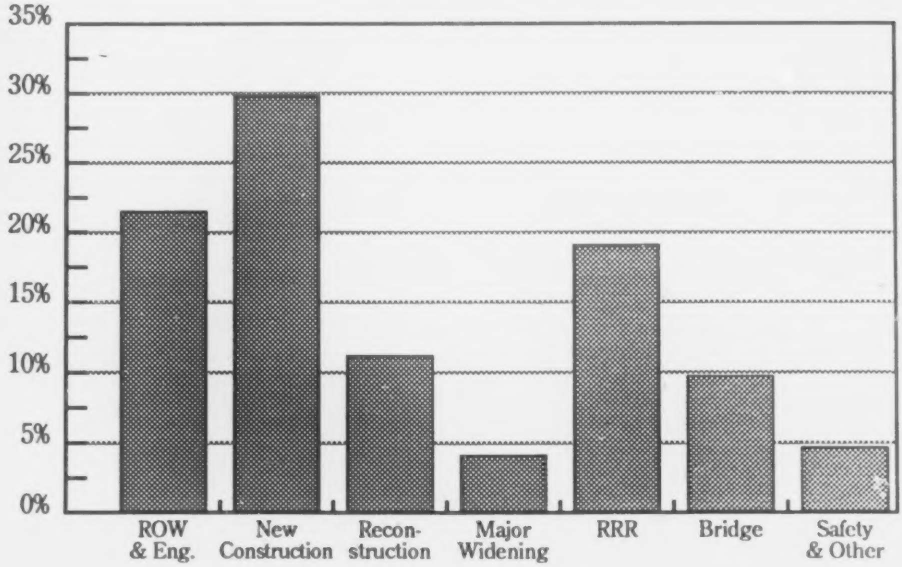


Exhibit 2-27
Distribution of Federal-Aid Primary System Capital Outlay
1989



Federal Urban and Secondary Systems

The next tier of Federal involvement addresses major "areawide" traffic generators under the Federal-aid urban and secondary (rural) systems.

The *Federal-Aid Urban System (FAUS)* functionally consists of the non-FAP urban principal arterials, most minor arterials, and over 70 percent of collectors in urban areas. Total capital outlays on the FAUS in 1989 were $3.6 billion. Expenditures per 1,000 VMT were $7.70 in 1989.

State and local governments are the primary funding sources for FAUS improvements (Exhibit 2-25). Federal funds account for 33 percent and State and local funds cover 67 percent of all capital costs.

Based on State expenditure data only, new construction accounts for approximately 20 percent of capital expenditures on the FAUS. This assumes that local spending patterns by improvement type are the same as State expenditure patterns. Because of high land values in urban areas, right-of-way (ROW) and engineering costs account for almost one-fourth of all FAUS costs (See Exhibit 2-28).

The *Federal-Aid Secondary (FAS) system* serves basically a rural collector or farm-to-market function. An estimated $2.7 billion was expended on the FAS system by all levels of government in 1989. The Federal Government provided 29 percent of these funds. Spending per 1,000 VMT was $15.06 in 1989.

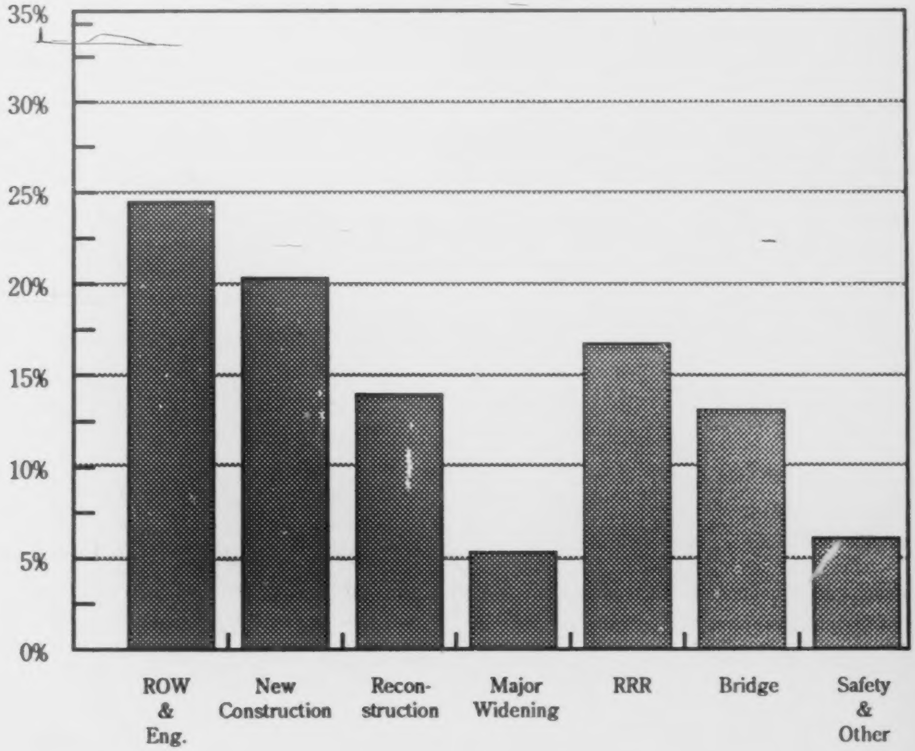
Most improvements on the FAS system involve the preservation of roads and bridges. Only one dollar in five goes toward new highways (See Exhibit 2-29).

Private Sector Financing of Highways

As mentioned in the Introduction, financing for roads and highways comes from both the public and private sectors. This section discusses the private sector componenent of highway finance.

Private sector financing includes projects funded and developed by the private sector, e.g., local roads that are part of a development project, intersection improvements required by a development agreement, etc. Private sector financing of roads that are part of a development project is a common practice and has been for a number of years. Projects of this type are often referred to as "on-site" development. Recently, private sector financing has expanded to include "off-site development," i.e., projects that are outside the boundaries of a specific development project. Projects of this type include improvements to an

Exhibit 2-28
Distribution of Federal-Aid Urban System Capital Outlay 1989

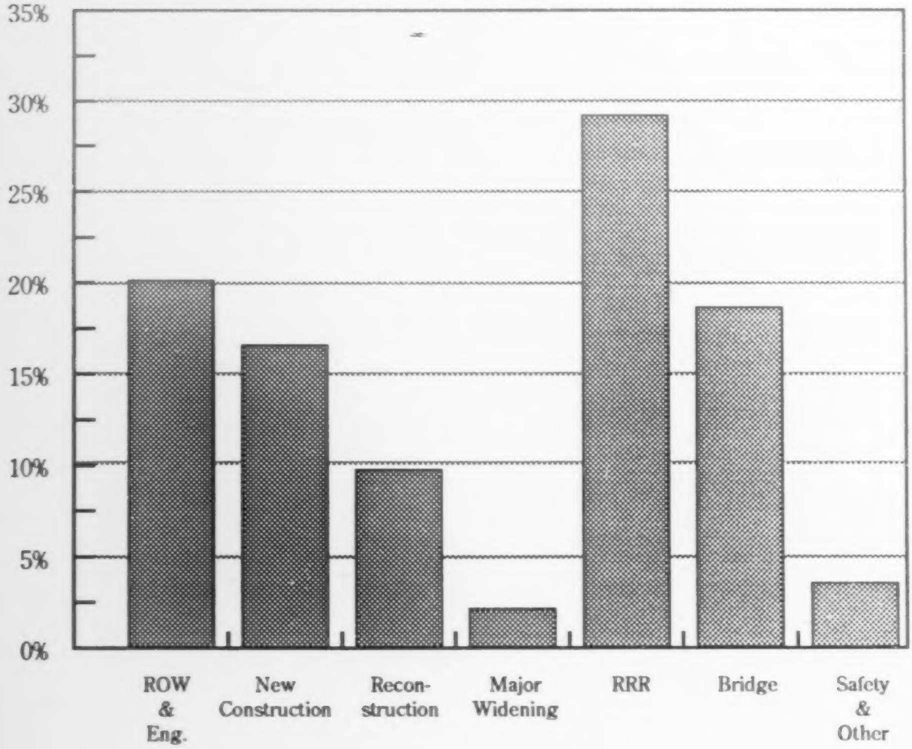


intersection, widening of an adjacent roadway that is impacted by a new development, a toll road developed by private investors, etc.

While there is a growing body of anecdotal evidence concerning private sector financing, there is very little hard data. It has been estimated that in 1989, $6.4 billion was invested by the private sector on on-site highway improvements and $3.2 ($2.1) billion off-site. However, these are extremely rough estimates and should be viewed as very preliminary. Further effort is needed to get better data on this important and growing area of highway financing.

Combined public and private sector financing for highways was estimated at approximately $83.2 billion in 1989.

Exhibit 2-29
Distribution of Federal-Aid Secondary System Capital Outlay
1989



Chapter 3
Highway Conditions and Performance

Summary

- **Congestion** — Urban Interstate and other arterial highways continue to experience significant congestion. The percent of peak-hour travel on urban Interstates that occurred under congested conditions reached almost 70 percent in 1989, up from 65 percent in 1987, and from 55 percent in 1983. The percent of peak-hour travel on urban other arterials (non-freeways) that occurred under congested conditions reached 45 percent, up from 42 percent in 1987. The duration of this level of congestion varies in different urban areas, with larger cities often experiencing longer periods of congestion. Less congestion occurs during mid-day and at night.

- **Pavement Condition** — For the period from 1983 through 1989, the percentage of pavements in poor condition decreased on all functional systems, rural and urban, except for urban collectors. This decrease was greatest on the urban Interstate mileage. For the 2-year period from 1987 to 1989, the amount of mileage with poor pavement continued to decline, again with the exception of urban collectors. Also, the amount of pavement in the "near poor" category has declined. This is pavement that is likely to need repair or resurfacing in the next few years. Overall, pavement condition ratings have stabilized.

- **Bridges** — The percentage of Interstate, arterial, and collector bridges classified as being deficient increased over the period from 1984 through 1990, from 30.9 percent to 32.5 percent. The proportion of Interstate bridges classified as being deficient rose from 13.1 percent in 1984 to 28.6 percent in 1990. A large portion of that increase is due to a change in reporting standards for these bridges. The percentage of deficient bridges on other principal arterial highways remained nearly constant during the same period, staying about 28 percent. The percentage of deficient collector bridges decreased from 39.2 percent to 34.5 percent between 1984 and 1990.

- **Fatalities** — Compared to 1987 the 1989 fatal accident rates decreased for urban and rural Interstate and other arterials and rural collectors while increasing slightly on urban collectors. The fatality rates ranged from a high of 3.67 persons per 100 million VMT on rural major collectors to a low of 0.82 on urban Interstate highways.

Introduction

This chapter addresses those features of the arterial and collector highways that affect condition and performance. Condition refers to the physical condition of the pavement, and performance refers to the degree of mobility (level of service) provided to traffic. Information is included about the highway systems in terms of congestion levels, pavement condition, bridge condition, and accidents.

The information contained in this chapter has been developed primarily from data supplied by the State highway agencies via the Highway Performance Monitoring System (HPMS) and the National Bridge Inventory (NBI). HPMS data, updated annually by the States, provide the FHWA with information about highway physical condition and usage. Data about pavement, roadway cross-section, alignment, and usage are collected for about 100,000 sample sections of highways nationwide. The samples represent all functional highway systems except local roads and streets.

The HPMS data are the primary sources of information for the Federal Government about the Nation's highway infrastructure. The HPMS is a statistical, sample-based system, which presents an estimate of pavement condition and system performance. Relative changes in conditions and performance over time should be considered more reliable than the absolute value of any condition or performance measure.

The second source of data, the National Bridge Inventory, is updated continuously and includes detailed information about all highway bridges in the country, on all functional systems. This information is used in the monitoring and managing of the Highway Bridge Replacement and Rehabilitation Program.

The latest data presented on highway physical conditions, other than the bridge data, were collected in 1989 and represent conditions that existed during that year. The bridge data are updated for each bridge, usually on a 2-year cycle. The bridge information presented in this chapter is based on the data on file June 30, 1990, which includes the most recent updates for each bridge, primarily from mid-1988 to mid-1990.

The material in this chapter is presented to characterize the relative differences among functional highway systems and changes that are occurring on those systems over time at the national level. The annual FHWA publication titled *Highway Statistics* contains information about the physical condition and usage of highways at the individual State level. Conditions and performance information contained in this chapter is presented primarily by functional highway system, with a brief summary by Federal-aid System. Information about the functional systems is presented in four major sections, which are:

- Operating Characteristics
- The Growth of Congestion
- Physical Conditions
- Safety

Conditions and Performance on the Functional Systems

Trends were examined for several condition and performance measures for the years 1983, 1985, 1987, and 1989. Consistent data are available from the HPMS sample section data for these years, and data are available for 37 States for each of these years. Analysis was stratified by the rural and urban functional classification systems. Results of these analyses are contained in the subsections that follow. The conditions and performance of local roads and streets are not included because they are not included in the HPMS sample section data, and no other comparable data exist.

Operating Characteristics

Continuing growth in travel has resulted in increasing congestion on the Nation's highways, particularly in urbanized areas. Congestion can be measured in a variety of ways. Earlier versions of this report have used the volume/capacity (V/C) ratio, the ratio between the volume of traffic actually using a highway facility and the theoretical capacity of that facility to accommodate this traffic.

This report historically has used a V/C ratio of 0.80, representing level of service D, as the threshold of congestion. We have reported that highways with a V/C ratio of greater than 0.80 were "congested." This volume of traffic is less than the maximum that can be accommodated, but stop-and-go conditions begin to occur at higher V/C ratios, and speeds drop significantly below those of a free-flow facility. Higher V/C ratios represent increasing congestion until level of service F is reached at a V/C ratio of about 1.0, approaching a "gridlock" condition.

There are other measures of congestion. The *extent* of congestion defines the geographic area, the portion of the population, or the portion of total travel affected. The *severity* of congestion refers to the magnitude of the problem, as measured by the average overall travel speed. The *duration* of congestion concerns the length of time that the traffic flow is congested, often referred to as the "peak period" of traffic flow.

Congestion, as expected, is concentrated in the urban areas, and on the higher functional systems. Interstates and other freeways and expressways have the highest levels of congestion, while other principal arterials and minor arterials have a lower but still significant amount.

There has been a consistent increase of travel relative to the capacity of the highway system to accommodate this travel. Exhibits 3-1 and 3-2 illustrate the daily vehicle miles of travel (DVMT) per lane-mile separately for each functional system, for the years 1983, 1985, 1987, and 1989, for rural and urban systems, respectively. These exhibits demonstrate the more rapid increase in travel on the higher functional systems, particularly the Interstates, both urban and rural, and other urban freeways and expressways. Travel per lane-mile on the rural

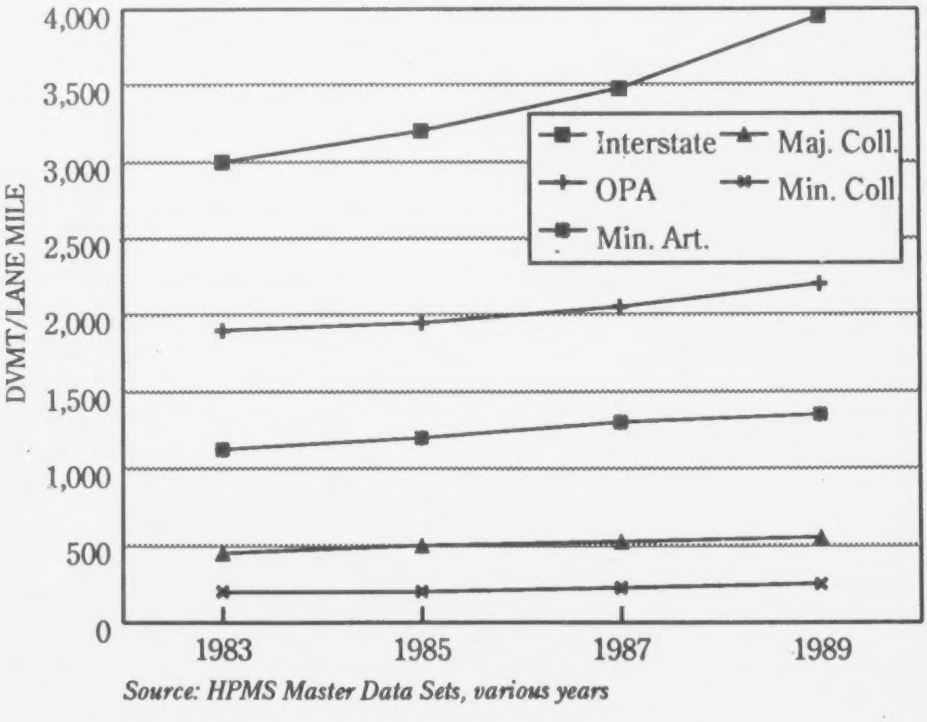
Interstates increased from about 3,000 vehicles per day to almost 4,000. On the urban Interstates, this number increased from approximately 11,000 to approximately 13,500.

This increase in travel relative to the supply of highway capacity is the reason for increasing congestion on the higher functional systems in the urbanized areas. The increase in rural travel has not yet saturated the facilities to the degree that has occurred in the large urbanized areas.

Exhibit 3-3 contains trends of the percent of ***mileage*** on which peak-hour travel occurred with volume to capacity ratios greater than or equal to 0.80, for 1983 to 1989, by functional system. The trends in these data indicate that an increasing portion of the urban mileage has become congested. While congested mileage on rural Interstate is also increasing at a rapid rate, from 3 percent in 1983 to almost 10 percent in 1989, the extent is still far less than in the urban areas, which increased from almost 31 percent to more than 45 percent.

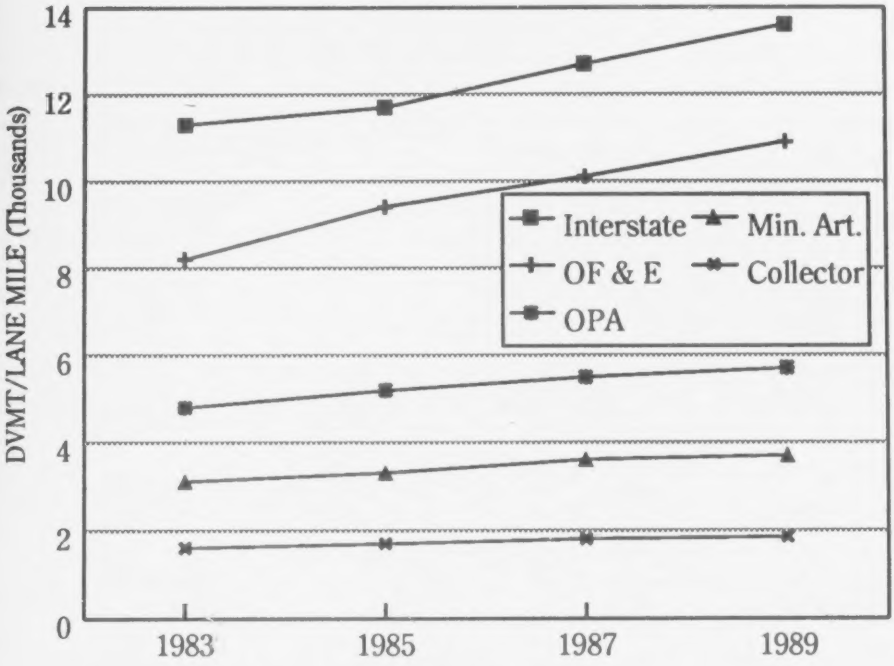
Exhibit 3-4 contains trends of the percent of peak-hour *travel* that occurred with volume to capacity ratios greater than or equal to 0.80, by functional system. The volume of travel that occurs under congested conditions is increasing at an even faster rate than the mileage involved. The percent of peak-hour travel on rural Interstates increased from about 8 percent to nearly 23 percent from 1983

Exhibit 3-1
DVMT per Lane Mile
Rural



Source: HPMS Master Data Sets, various years

Exhibit 3-2
DVMT per Lane Mile
Urban



Source: HPMS Master Data Sets, various years

Exhibit 3-3
Congested Highway Mileage by Functional System
(in percent)

Functional System	1983	1985	1987	1989
Rural				
Interstate	2.99	3.50	7.65	9.78
Other Principal Arterial	2.74	3.22	2.10	2.16
Minor Arterial	1.99	2.40	1.16	1.33
Major Collector	0.49	0.64	0.29	0.33
Minor Collector	0.17	0.06	0.07	0.02
Urban,				
Interstate	30.63	38.06	42.01	45.58
Other Freeway & Expressway	22.79	28.03	31.29	33.41
Other Principal Arterial	28.45	30.24	29.96	30.82
Minor Arterial	17.11	18.19	18.32	18.96
Collector	5.96	6.66	6.03	6.91

Source: HDMS Master Datasets, 1983 – 1989 to 1989. The percent of peak-hour travel on urban Interstates increased from about 55 percent to nearly 70 percent.

The Growth of Congestion

This section is based on several research efforts designed to estimate the levels of congestion in a number of the major cities in the nation. These research projects used different measures of congestion than are used elsewhere in this report, so direct comparisons with other sections or chapters are not possible. This information is included to present a picture of congestion in the larger cities not otherwise available in this report.

Supply and Demand

The supply of both miles and lane-miles of freeways and arterials increased slowly during the last several years. In 1984 there were 66,315 miles of freeways and principal arterials in urbanized areas, while in 1989 there were 70,542 miles, a 6.4-percent increase in 5 years. The number of lane-miles increased from 244,350 to 266,570, an increase of 9.1 percent.

Travel grew at a faster rate than the capacity supply. In 1984 the DVMT on freeways and principal arterials in urbanized areas was 568 billion vehicle miles of travel, while in 1989 the DVMT was almost 720 billion, an increase of 26.7 percent. The rate of travel increase was 2.9 times the rate of increase in highway lane-mileage and 4.2 times the rate of increase in highway mileage between 1984 and 1989.

Exhibit 3-4
Congested Peak Hour Travel by Functional System (in percent)

Functional Class	1983	1985	1987	1989
Rural				
Interstate	8.49	9.35	18.92	22.90
Other Principal Arterial	8.82	9.53	7.80	8.16
Minor Arterial	8.83	10.01	5.60	6.33
Major Collector	5.32	6.37	3.23	3.93
Minor Collector	4.22	1.54	1.59	0.62
Urban				
Interstate	55.39	62.67	66.99	69.56
Other Freeway & Expressway	49.27	54.36	56.95	59.93
Other Principal Arterial	40.31	42.36	43.29	44.99
Minor Arterial	31.66	33.52	34.17	34.48
Collector	19.50	20.04	18.03	19.47

Source: HPMS Master Datasets, 1983 – 1989

The congestion analysis technique described in this section requires the analysis of traffic operations on individual highway segments within an individual urbanized area. Some States group their urbanized areas and obtain HPMS sample highway sections from this pool. Data from most grouped areas could not be included in this congestion trend analysis because complete HPMS sample data from each urbanized area are not available.

This analysis includes only Interstate freeways and other freeways and expressways. Other principal arterials were not included in the congestion analysis because further research would be required to perform a broad-scale analysis of congestion on roads with traffic controls and conflicting vehicular movements.

A freeway with near capacity traffic.

Special Analysis of 20 Urbanized Areas

A group of 20 urbanized areas was selected for use in this examination of national-level trends in urbanized area congestion. The 20 areas were selected to be representative of each of four population groups over 200,000 and of all FHWA regions. Exhibit 3-5 contains a list of the 20 selected areas by population group and FHWA region.

The research on which this section is based defined congestion as DVMT experiencing level of service (LOS) F operation on the freeways. This is when the V/C ratio is effectively 1.0. This is a conservative measure of congestion, chosen to provide a very restrained picture of congestion in these 20 urbanized areas. Considering the extent of severe congestion shown by this measure, the use of LOS D as the threshold of congestion would show a much greater extent of congestion in these areas.

Exhibit 3-6 graphically illustrates the growth of freeway mileage, freeway lane-mileage, freeway DVMT, and congested peak-hour freeway DVMT for the 20 urbanized areas. The supply of capacity, represented by freeway miles and lane-miles, grew at a significantly slower rate than the travel. The portions of travel that experienced severe congestion grew at an even faster rate than did the overall travel.

Freeway mileage in the study areas increased from 3,377 miles in 1985 to 3,579 miles in 1988, a 6.0-percent increase. Similarly, freeway lane-mileage increased from 17,904 in 1985 to 19,515 in 1988, an increase of 9.0 percent. Total annual freeway travel in these areas increased from 206 billion VMT in 1985 to

Exhibit 3-5
Selected Urbanized Areas by FHWA Region and Population for Congestion Trends Analysis

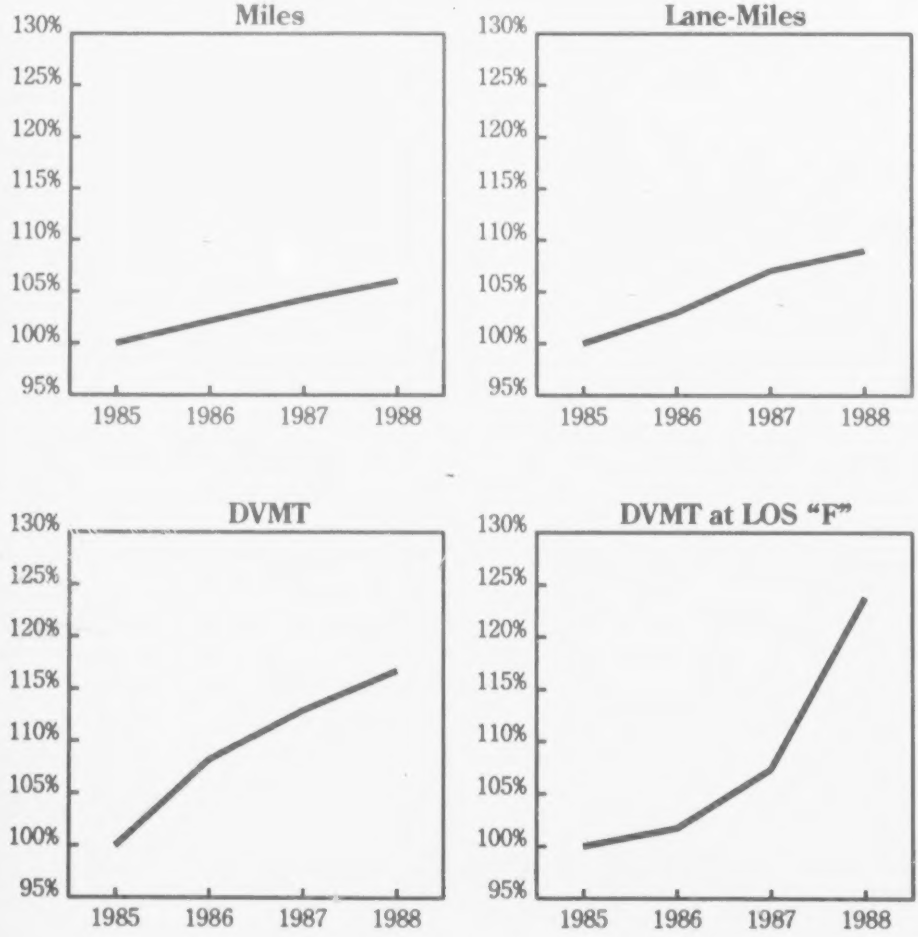
	Urbanized Areas by Population			
FHWA Region	> 2,000,000	1,000,000 – 2,000,000	500,000 – 1,000,000	200,000 – 500,000
1	New York City	—	Providence	Lawrence-Haverhill
3	Philadelphia	—	Norfolk-Portsmouth	Wilmington
4	—	Atlanta	Birmingham	—
5	Chicago	—	Dayton	—
6	Dallas-Fort Worth	—	—	Albuquerque, Tulsa
7	—	—	Omaha	Wichita
8	—	Denver	Salt Lake City	—
9	—	Phoenix	—	Las Vegas
10	—	—	—	Anchorage

Source: FHWA Table HM-23, December 31, 1988

240 billion VMT in 1988, a total of 16.7 percent. The demand for freeway travel increased at a rate 1.9 times greater than the rate of freeway lane-mile supply increase, and 2.8 times greater than the rate of freeway centerline mileage increase.

The trend in travel occurring under congested conditions in the 20 selected urbanized areas follows the expected pattern. The results show an increase from 10,665,000 DVMT experiencing LOS F in 1985 to 15,416,000 DVMT experiencing LOS F in 1988. This results in an increase in the total DVMT operating under severely congested conditions of 45 percent between 1985 and 1988. Part of this increase in the amount of congested travel is due to an overall increase in travel, and part is due to an increase in the portion of travel that operates under congested conditions. The portion of total freeway travel operating under severely congested conditions increased from 5.2 percent to 6.4 percent, or a

Exhibit 3-6
Urban Freeways Demand and Supply
(20 Selected U.S. Urbanized Areas)



23-percent increase. Total congested DVMT in the 20 selected urbanized areas increased 4.9 times faster than the rate of freeway lane-mile supply increase.

Freeways have been designed to accommodate large volumes of traffic at higher rates of flow than can be accommodated by city streets. However, many of the freeways in the urbanized areas of the country have become very congested. While average overall travel speeds on freeways may still be higher than on city streets, the flow is much slower than envisioned by the designers — speeds during congested periods may not be much faster than on city streets.

Congestion is a growing problem in all of the large cities in the country. This is true in the suburban areas as well as in the city centers. The travel delays caused by congestion are a significant cost to the public. Further increases in travel demand will increase the burden on the urban transportation systems, and the additional costs will be born by the public as user costs, agency costs, or both.

Physical Conditions

The pavement condition evaluations are based on the present serviceability rating (PSR) system. Exhibit 3-7 contains a description of this rating system.

Pavement Condition

To show the highway mileage that needs pavement improvements, the mileage of pavements in poor condition has been listed. For both urban and rural systems the portion of pavement in poor condition has declined since 1983. Exhibit 3-8 contains the mileage distribution, for 1989, by three categories of pavement condition rating. The first numeric column of this table contains the percentages of mileage on each functional system where the PSR values were less than or equal to 2.0. For Interstate highways, that have a higher condition standard, the values represent pavement less than or equal to 2.5. While the actual PSR value to identify a deficient pavement varies by functional system, the values in this table provide a general definition of pavement in poor, fair, and good condition.

Exhibit 3-9 contains the percent of mileage in three categories of pavement condition, also for the years 1983, 1985, 1987, and 1989. Column (1) contains the percent of miles rated in poor condition, column (2) contains pavement that is rated poor plus a portion of the pavement rated fair (near poor), and column (3) contains pavement in good and very good condition. The pavement in poor condition needs improvement now. The additional pavement in column (2) will need improvement in the near future, perhaps within the next 5 years, depending on the pavement design, environmental factors, and the traffic loading. The pavement in very good condition may not need improvement for 10 to 15 years or more.

The mileage in column (1), which represents poor pavement, decreased for all functional classes except under collector.

Exhibit 3-7
Present Serviceability Rating (PSR)

PSR	Verbal Rating	Description
5		
	Very Good	Only new (or nearly new) pavements are likely to be smooth enough and sufficiently free of cracks and patches to qualify for this category. All pavements that have been recently constructed or resurfaced should be rated in this category.
4		
	Good	Pavements in this category, although not quite as smooth as those described above, give a first class ride and exhibit few, if any visible signs of surface deterioration. Flexible pavements may be beginning to show evidence of rutting and fine random cracks. Rigid pavements may be beginning to show evidence of slight surface deterioration, such as minor cracks and spalling.
3		
	Fair	The riding qualities of pavements in this category are noticeably inferior to those of new pavements, and may be barely tolerable for high-speed traffic. Surface defects of flexible pavements may include rutting, map cracking, and extensive patching. Rigid pavements in this group may have a few joint failures, faulting and cracking, and some pumping.
2		
	Poor	Pavements that have deteriorated to such an extent that they affect the speed of free-flow traffic. Flexible pavement may have large potholes and deep cracks. Distress includes ravelling, cracking, rutting, and occurs over 50 percent or more of the surface. Rigid pavement distress includes joint spalling, faulting, patching, cracking, scaling, and may include pumping and faulting.
1		
	Very Poor	Pavements that are in extremely deteriorated condition. The facility is passable only at reduced speeds and with considerable ride discomfort. Large potholes and deep cracks exist. Distress occurs over 75 percent or more of the surface.
0		

Source: *HPMS Field Manual*, 1987

Exhibit 3-8
1989 Mileage by Functional System and Pavement Condition (in percent)

	PSR Range			
Functional System	0.0 – 2.0* (Poor)	2.1 – 3.4* (Fair)	3.5 – 5.0 (Good)	Unpaved
Rural				
Interstate	9.3	32.5	58.2	0.0
Other Principal Arterial	4.5	43.6	51.9	0.0
Minor Arterial	5.1	49.3	45.5	0.1
Major Collector	9.5	45.0	34.2	11.3
Minor Collector	12.1	33.9	20.3	33.7
Urban				
Interstate	9.7	32.9	57.4	0.0
Other Freeway & Expressway	2.7	44.6	52.7	0.0
Other Principal Arterial	6.3	50.9	42.7	0.1
Minor Arterial	9.4	49.4	40.7	0.5
Collector	17.7	49.6	31.3	1.4

*For Interstate highways, the "poor" range is 0.0 – 2.5 and the "fair" range is 2.6 – 3.4.
For an explanation of PSR, refer to Figure 4-1.
Source: *Highway Statistics*, 1989

The mileage in column (2) of Exhibit 3-9, which represents mileage that will soon need improvement, has decreased between 1983 and 1989 for all the functional system categories. Also, the amount of mileage in column (3), the very good category, has increased or stabilized for each functional system. The Interstate mileage in the good category has declined less than 1 percent, and the other arterial and collector mileage had increased.

While the reduction in miles of pavement in poor condition is not entirely consistent for all functional systems, the overall trend is clear. These trends are illustrated in Exhibits 3-10 and 3-11. Exhibit 3-10 contains the trend for rural functional systems, and Exhibit 3-11 contains the trends for urban functional systems. These graphics clearly show that, except for the urban collector system, the trend for every functional system is toward less mileage in the poor category in 1989 than in 1983.

Exhibit 3-12 contains the percent of arterial and collector pavement in poor condition for 1983, 1985, 1987, and 1989, for each State. Exhibit 3-13 contains the percent of total travel occurring on arterial and collector highways with poor pavement in each State for the same series of years. This exhibit shows that a significant percent of travel occurs on poor pavement.

Exhibit 3-9
Estimated Highway Mileage by Pavement Conditions, Functional System and Year

		Present Serviceability Rating[1]		
Functional System	Year	(1) Less Than or Equal to 2.0[2]	(2) Less Than or Equal to 3.0	(3) Greater Than or Equal to 4.0
Rural Interstate	1983	13.1	26.1	31.8
	1985	10.8	24.1	33.8
	1987	11.6	27.2	29.9
	1989	9.3	24.7	30.7
Urban Interstate	1983	17.5	33.9	30.1
	1985	11.1	29.0	35.3
	1987	11.1	29.0	29.4
	1989	9.8	26.1	29.8
Rural Other Arterials	1983	10.6	43.6	20.1
	1985	8.3	38.9	23.8
	1987	6.0	37.9	22.1
	1989	4.8	33.9	23.1
Urban Other Arterials	1983	10.1	48.6	20.1
	1985	9.0	46.9	24.2
	1987	8.1	44.6	22.9
	1989	7.7	43.8	23.3
Rural Collector	1983	17.2	56.9	15.2
	1985	16.5	58.6	15.6
	1987	14.5	54.1	16.8
	1989	13.1	51.7	18.5
Urban Collector	1983	15.9	58.1	16.1
	1985	13.4	56.4	16.7
	1987	13.0	56.9	16.1
	1989	17.6	57.7	16.7

[1] Refer to Exhibit 3-7 for an explanation of PSR values.

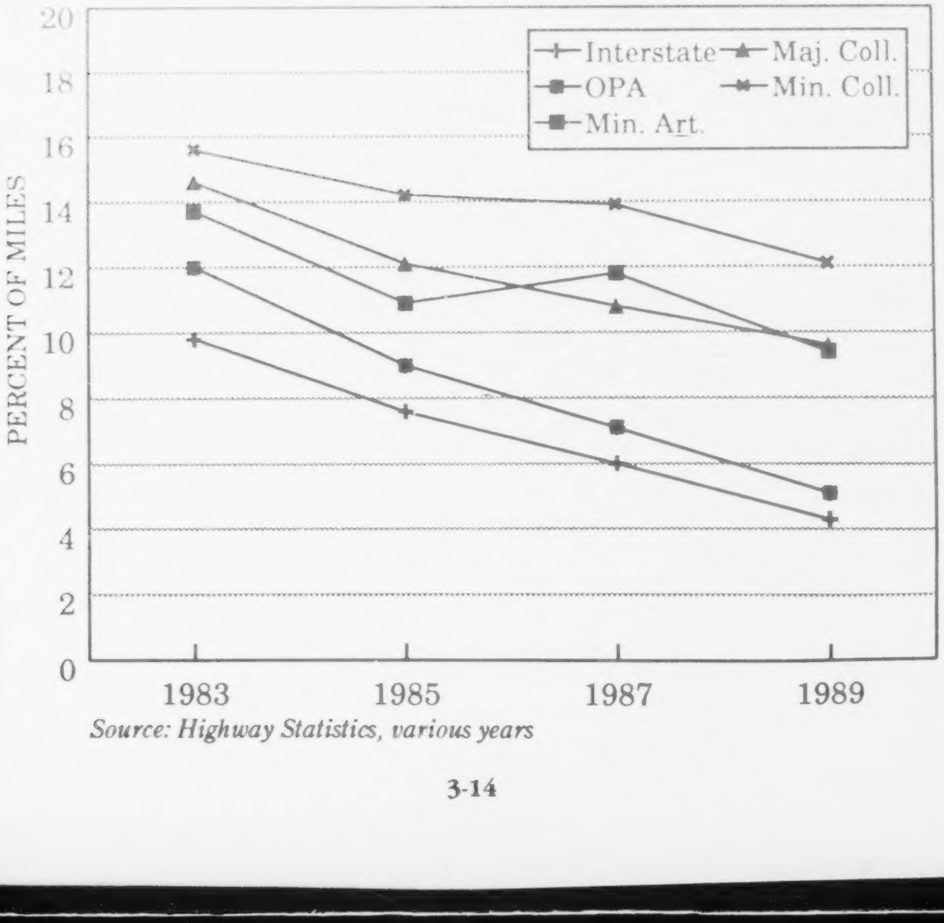
[2] Less than 2.5 for Interstate

Note: The pavement service rating categories above represent: (1) pavement that needs improvement, (2) pavement that needs or may soon need improvement, and (3) pavement that is in very good condition. Note that (2) includes (1); (1), (2), and (3) do not sum to 100 percent.

Source: *HPMS Master Datasets*, Summary Tables, 1983-89.

Pavement in poor condition

Exhibit 3-10
Rural
PSR ≤ 2.0 (2.5 for Interstate)



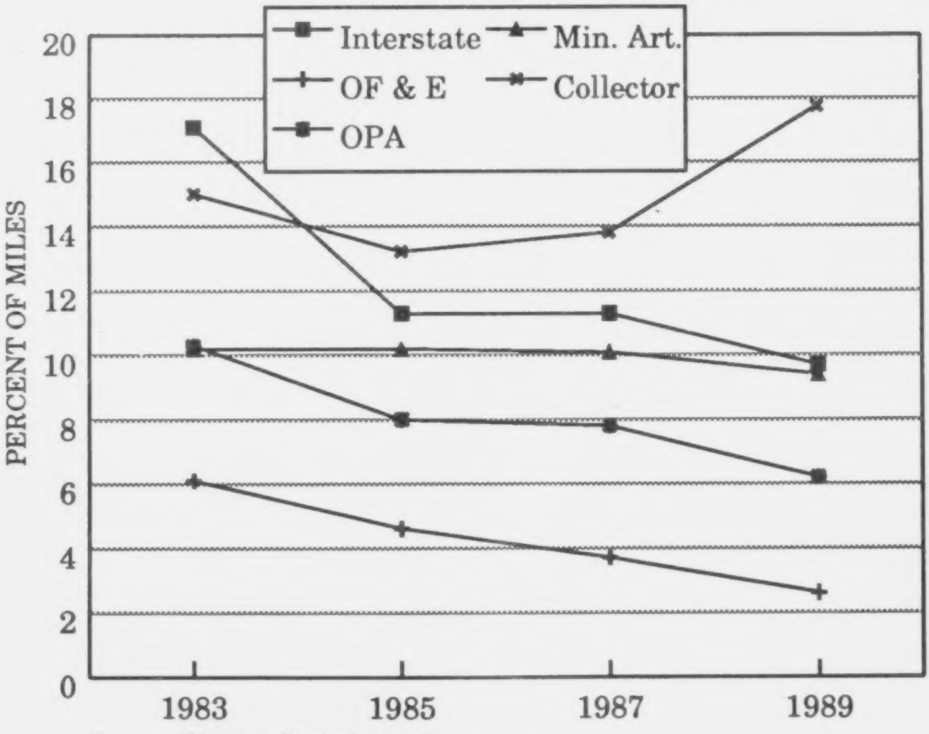
Source: Highway Statistics, various years

While there is substantial variation among the States as to the amount of pavement that needs or soon will need improvement, the amount in poor condition has declined over the past few years. This represents a real accomplishment in addressing the worst pavement needs. States have implemented pavement management systems that are contributing to the decline in the quantity of poor pavement. However, because of the traffic loads and the environment, pavements will continue to deteriorate and resurfacing and rehabilitation will be required to maintain the pavement structure in an acceptable condition.

Alignment and Lane Width

There are other physical highway characteristics in addition to pavement condition that have a major effect on highway performance. Among these are alignment and lane width, both of which contribute to the service flow and safety of a highway. A summary of both horizontal and vertical alignment adequacy on rural highway mileage for 1989 is contained in Exhibit 3-14. Alignment is rarely a major problem in urban areas, and therefore is not shown here. The rating system used for alignment adequacy is found at the bottom of this table. Less than 2 percent of rural Interstate miles are given the low ratings for horizontal alignment adequacy (code 3 or 4, which is significantly below design

Exhibit 3-11
Urban
PSR ≤ 2.0 (2.5 for Interstate)



Source: Highway Statistics, various years

Exhibit 3-12
Pavements in Poor Condition – All Systems
PSR ≤ 2.0 (2.5 for Interstate)
(in percent)

State	1983	1985	1987	1989
Alabama	15.4	19.3	20.2	15.5
Alaska	18.2	18.3	37.4	15.6
Arizona	9.4	9.8	11.5	23.5
Arkansas	29.8	30.8	18.2	13.1
California	9.5	8.8	9.6	10.6
Colorado	11.7	7.8	9.1	7.2
Connecticut	10.1	12.8	5.7	3.6
Delaware	41.7	13.3	10.7	12.0
District of Columbia	7.4	11.5	6.4	9.5
Florida	10.0	9.3	10.0	10.1
Georgia	11.5	2.3	12.3	11.0
Hawaii	15.2	14.1	12.9	10.4
Idaho	23.6	47.8	23.2	27.7
Illinois	8.4	5.3	4.6	3.3
Indiana	11.2	15.1	15.2	13.2
Iowa	3.7	3.7	4.4	2.9
Kansas	30.1	18.5	15.3	14.8
Kentucky	23.1	18.8	14.0	11.9
Louisiana	24.8	13.6	13.0	13.9
Maine	10.7	11.1	6.4	13.6
Maryland	12.0	4.8	4.2	5.4
Massachusetts	3.3	4.6	8.1	10.1
Michigan	28.6	4.9	6.8	10.8
Minnesota	0.6	2.1	1.2	2.2
Mississippi	49.3	14.4	37.0	22.9
Missouri	11.8	18.2	17.2	10.7
Montana	17.5	14.8	17.8	17.3
Nebraska	9.0	7.2	7.3	13.6
Nevada	4.4	5.2	8.7	12.7
New Hampshire	14.9	14.5	23.3	25.2
New Jersey	4.3	15.4	12.3	11.4
New Mexico	52.5	52.7	9.0	7.7
New York	12.0	4.0	2.8	2.5
North Carolina	12.0	10.0	7.4	5.4

Exhibit 3-12
(cont.)

State	1983	1985	1987	1989
North Dakota	0.1	0.0	6.3	1.8
Ohio	4.4	9.3	9.5	7.5
Oklahoma	25.2	31.9	34.4	6.1
Oregon	27.9	19.0	16.4	14.2
Pennsylvania	23.3	18.7	21.3	17.2
Rhode Island	32.6	29.2	25.7	26.8
South Carolina	18.2	11.4	5.5	2.5
South Dakota	10.3	14.7	12.0	12.1
Tennessee	43.3	37.2	37.7	13.5
Texas	17.8	16.1	7.4	5.0
Utah	4.8	3.7	3.7	3.6
Vermont	7.2	6.4	6.0	6.2
Virginia	10.8	6.1	10.9	10.4
Washington	7.6	6.0	4.7	2.3
West Virginia	13.7	28.9	22.0	19.1
Wisconsin	13.6	13.7	12.7	10.2
Wyoming	9.0	6.5	5.1	5.2

Exhibit 3-13
DVMT on Poor Pavements
PSR ≤ 2.0 (2.5 for Interstate)
(in percent)

State	1983	1985	1987	1989
Alabama	4	6	6	3
Arkansas	18	18	10	7
California	8	5	6	6
Connecticut	6	6	3	1
Delaware	30	7	5	8
District of Columbia	17	14	11	15
Georgia	6	1	8	7
Illinois	9	5	4	3
Iowa	7	7	10	6
Kansas	37	32	11	9
Kentucky	11	11	7	8
Maine	9	9	6	7
Maryland	11	2	2	3
Michigan	3	3	4	3
Minnesota	2	2	2	2
Mississippi	28	30	27	8
Missouri	20	21	25	24
Montana	8	14	18	18
Nebraska	7	4	2	8
Nevada	5	4	5	15
New Hampshire	5	5	8	10
New Jersey	7	9	7	9
New York	9	4	4	3
North Carolina	9	7	5	3
North Dakota	1	0	10	3
Ohio	9	8	9	7
Oregon	31	24	20	15
Pennsylvania	10	9	8	7
Rhode Island	24	25	16	16
South Dakota	7	6	5	4
Tennessee	5	8	17	11
Texas	16	14	8	4
Utah	4	4	2	1
Virginia	8	6	8	12
Washington	10	3	2	1
Wisconsin	13	13	15	11
Wyoming	5	1	1	1

Exhibit 3-14
Rural Highway Mileage by Alignment Adequacy and Functional System (in percent)

	Horizontal Alignment Adequacy Ratings			
Functional System	Code 1	Code 2	Code 3	Code 4
Interstate	94.3	3.9	1.0	0.6
Other Principal Arterial	74.5	15.1	6.2	4.0
Minor Arterial	68.8	11.4	9.2	10.4
Major Collector	50.4	21.9	16.8	10.7
Minor Collector	38.7	25.7	20.2	15.3
Total	55.0	19.6	14.6	10.7
	Vertical Alignment Adequacy Ratings			
Interstate	92.1	6.2	0.2	1.3
Other Principal Arterial	68.3	25.4	3.7	2.4
Minor Arterial	56.1	32.1	6.7	4.9
Major Collector	47.7	32.1	13.7	6.3
Minor Collector	42.1	34.0	15.7	7.1
Total	51.6	31.1	11.4	5.7

Code 1 All grades/curves meet appropriate design standards.

Code 2 Some grades/curves are below design standards for new construction, but curves can be negotiated safely at prevailing speed limits. Truck speed is not substantially affected.

Code 3 Infrequent curves impair sight distance or affect truck speed. Infrequent curves may have reduced speed limits for safety purposes.

Code 4 Frequent grades that impair sight distance or severely affect truck speeds. General curves are unsafe and/or uncomfortable at prevailing speed limit, or the speed limit is severely restricted due to the design speeds of the curves.

Note: Paved mileage only. Sections for which no alignment data were supplied are treated as Code 2.

Source: 1989 HPMS Summary Tables

Exhibit 3-15
Rural Highway Mileage and Travel by Lane Width and Functional System (in percent)

	Mileage				
Functional System	Less Than 9 Feet	9 Feet	10 Feet	11 Feet	12 Feet or More
Interstate	0.0	0.0	0.0	0.6	99.4
Other Principal Arterial	0.0	0.3	2.8	9.8	87.1
Minor Arterial	0.3	2.7	12.3	19.3	65.4
Major Collector	2.8	10.4	30.2	22.9	33.7
Minor Collector	12.4	21.7	29.4	16.2	20.3
Total	4.9	11.44	24.1	18.6	41.0
	Travel				
Interstate	0.0	0.0	0.0	0.1	99.9
Other Principal Arterial	0.0	0.1	2.5	8.3	89.0
Minor Arterial	0.1	1.9	10.5	20.3	67.2
Major Collector	0.7	7.0	25.1	22.3	44.9
Minor Collector	6.3	19.9	34.1	20.0	19.7
Total	0.6	3.5	11.3	13.1	71.6

*Reported as "less than 12 feet."

Source: *Highway Statistics,* 1989 (Mileage, 1989 HPMS Summary Tables (Travel).

standards for new highways). In contrast, over 35 percent of rural minor collector miles are given the low ratings of 3 or 4. Similar distributions are found in the vertical alignment adequacy ratings.

Exhibit 3-15 contains similar information for the disuributions of rural lane widths. More than 99 percent of the rural Interstate mileage has a lane width of 12 feet or more. These percentages for rural highways dropped to 87 percent for other principal arterials, 65 percent for minor arterials, 34 percent for major collectors, and about 20 percent for minor collectors. In fact, over 12 percent of the rural minor collector mileage has lane widths of less than nine feet. However, only about 6 percent of minor collector travel occurs on roads with these very narrow lanes. Once again, the higher service functional systems with the higher travel densities generally have the better physical characteristics.

Bridge Conditions

The proportions of bridges that are classified as being structurally or functionally deficient are found in Exhibits 3-16 through 3-18. Most bridges that are structurally deficient are not in danger of collapse, but they are likely to be load-posted so that the heavier trucks will have to take an alternative longer

Exhibit 3-16
Interstate Bridge Deficiencies, 1984 – 1990

	1984		1986		1988		1990	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Rural Bridges	27,261		27,228		28,603		29,171	
Deficient Bridges	2,880	10.6	3,136	11.5	3,640	12.7	6,811	23.3
Structural	1,001	3.7	1,311	4.8	1,503	5.3	1,521	5.2
Functional	1,879	6.9	1,825	6.7	2,137	7.5	5,290	18.1
Urban Bridges	20,766		21,693		22,827		24,012	
Deficient Bridges	3,396	16.4	3,855	17.8	4,555	20.0	8,397	35.0
Structural	1,426	6.9	1,729	8.0	2,353	10.3	2,327	9.7
Functional	1,970	9.5	2,126	9.8	2,202	9.7	6,070	25.3
Total Bridges	48,027		48,921		51,430		53,183	
Deficient Bridges	6,276	13.1	6,991	14.3	8,195	15.9	15,208	28.6
Structural	2,427	5.1	3,040	6.2	3,856	7.5	3,848	7.2
Functional	3,849	8.0	3,951	8.1	4,339	8.4	11,360	21.4

Sources: National Bridge Inventory

Exhibit 3-17
Other Arterials Bridge Deficiencies, 1984 – 1990

	1984		1986		1988		1990	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Rural Bridges	74,323		74,040		73,573		72,997	
Deficient Bridges	19,797	26.6	20,293	27.4	20,705	28.1	18,639	25.5
Structural	7,680	10.3	8,436	11.4	8,744	11.9	8,430	11.5
Functional	12,117	16.3	11,857	16.0	11,961	16.3	10,209	14.0
Urban Bridges	44,627		46,639		49,133		51,618	
Deficient Bridges	12,873	28.8	13,779	29.5	14,317	29.1	20,852	40.4
Structural	5,583	12.5	6,727	14.4	7,618	15.5	7,559	14.6
Functional	7,290	16.3	7,052	15.1	6,699	13.6	13,293	25.8
Total Bridges	118,950		120,679		122,706		124,615	
Deficient Bridges	32,670	27.5	34,072	28.2	35,022	28.5	39,491	31.7
Structural	13,263	11.2	15,163	12.6	16,362	13.3	15,989	12.8
Functional	19,407	16.3	18,909	15.7	18,660	15.2	23,502	18.9

Sources: National Bridge Inventory

route. Functionally deficient bridges are those that do not have the lane widths, shoulder widths, or vertical clearances adequate to serve the traffic demand; or the waterway of the bridge may be inadequate and may allow flooding of the roadway on some occasions. Bridge conditions also experience a marked difference across the functional systems.

In general, the higher functional systems have fewer deficient bridges than the lower systems. The major increase in deficient bridges from 1988 to 1990, especially on the Interstate System bridges, results from changes in the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, December 1988. More specific criteria are used to assess condition and identify deficient bridges. In 1990, 28.6 percent of the Interstate bridges were classified as being deficient, compared to 27.7 percent on non-Interstate arterials, and 34.5 percent on the collector systems.

In the years not affected by the change in reporting criteria (1984 to 1988), the proportion of deficient Interstate bridges increased from 13.1 percent in 1984 to 15.9 percent in 1988. This is indicative of the heavy use of the Interstate System and of the fact that many of these bridges are nearing the point when rehabilitation will be needed. On the other arterial bridges, the proportion of deficient bridges increased from 27.5 to 31.7 over the same 6-year period. The proportion of deficient bridges on the collector systems decreased from 39.2 to 34.5.

Exhibit 3-19 contains the distribution of average overall bridge conditions by functional system. The rating scale is from 9 to 0, with 9 being new condition and 0 being so poor as to be unusable. Bridges that are rated 7 to 9 are in good to excellent condition. Bridges with a condition rating of 5 or 6 have some

Exhibit 3-18
Collector Bridge Deficiencies, 1984 – 1990

	1984		1986		1988		1990	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Rural Bridges	141,804		146,442		153,180		152,435	
Deficient Bridges	55,926	39.4	57,283	39.1	58,942	38.5	51,145	33.6
Structural	24,703	17.4	28,851	19.7	29,829	19.5	30,703	20.1
Functional	31,223	22.0	28,432	19.4	29,113	19.0	20,442	13.4
Urban Bridges	10,691		11,510		11,355		11,865	
Deficient Bridges	3,848	36.0	4,151	36.1	3,791	33.4	5,477	46.2
Structural	1,812	17.0	2,114	18.4	2,252	19.8	2,353	19.8
Functional	2,036	19.0	2,037	17.7	1,539	13.6	3,124	26.3
Total Bridges	152,495		157,952		164,535		164,300	
Deficient Bridges	59,774	39.2	61,434	38.9	62,733	38.1	56,622	34.5
Structural	26,515	17.4	30,965	19.6	32,081	19.5	33,056	20.1
Functional	33,259	21.8	30,469	19.3	30,652	18.6	23,566	14.4

Sources: National Bridge Inventory

deficiencies, and are considered fair or satisfactory. Bridges rated 4 or less are in poor to critical condition. The values in the figures are an average of deck, superstructure, and substructure condition ratings, weighted by the deck area of each bridge. The largest segment is rated as "7" which is good condition. However, there are a significant number of bridges in very poor condition.

Safety

Exhibits 3-20 and 3-21 display highway fatality rates for the years 1979 through 1989, for rural and urban highways, respectively. Accident rates are affected by many factors other than highway condition and performance, including weather conditions, number of intoxicated drivers, extent of police exposure, law enforcement, vehicle speed variations, and driver performance. An overall improvement in highway safety has occurred over the last several years.

For the most recent period, 1987 through 1989, the fatality rates decreased on the urban and rural Interstate System, the urban and rural arterial highways and on the rural collector system. The fatality rates increased somewhat on the urban collector system, from 1.51 to 1.67. In 1989, fatality rates ranged from a low of 0.82 fatalities per 100 million VMT on the urban Interstate System to a high of 3.67 on the rural collector system, with an overall average weighted by travel of 2.16. These data are obtained from the Fatal Accident Reporting System managed by the National Highway Transportation Safety Administration.

Exhibit 3-19
1989 Bridge Conditions
Percent of Deck Area

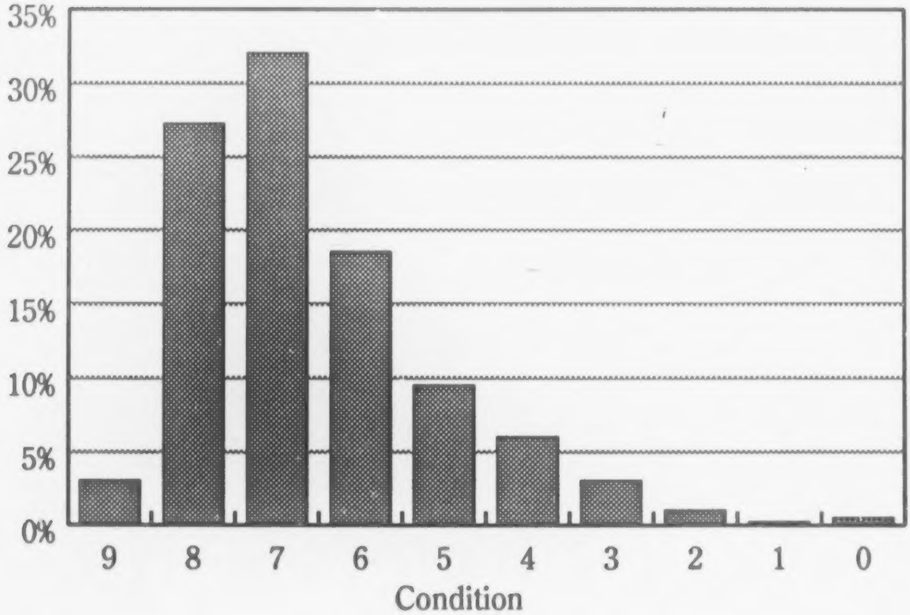
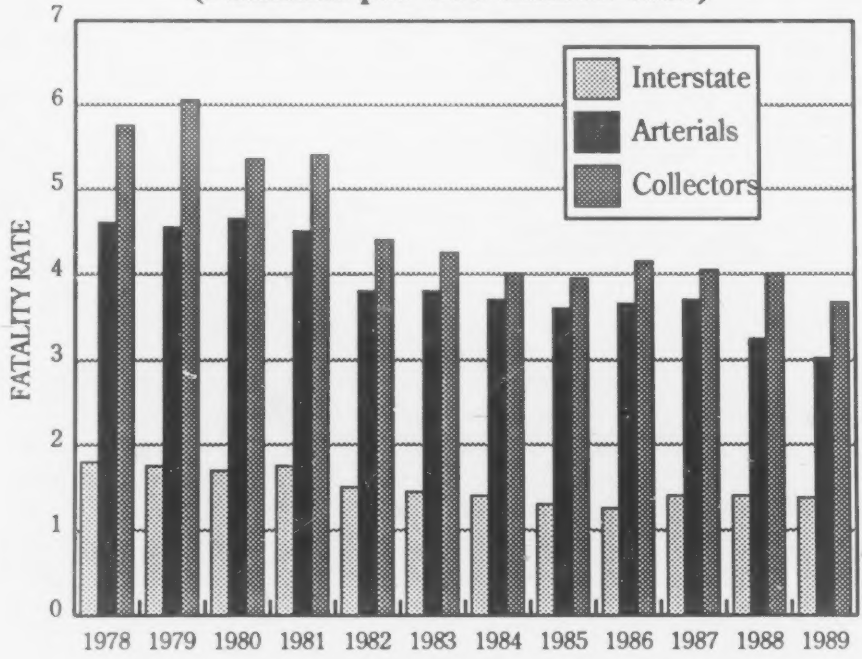
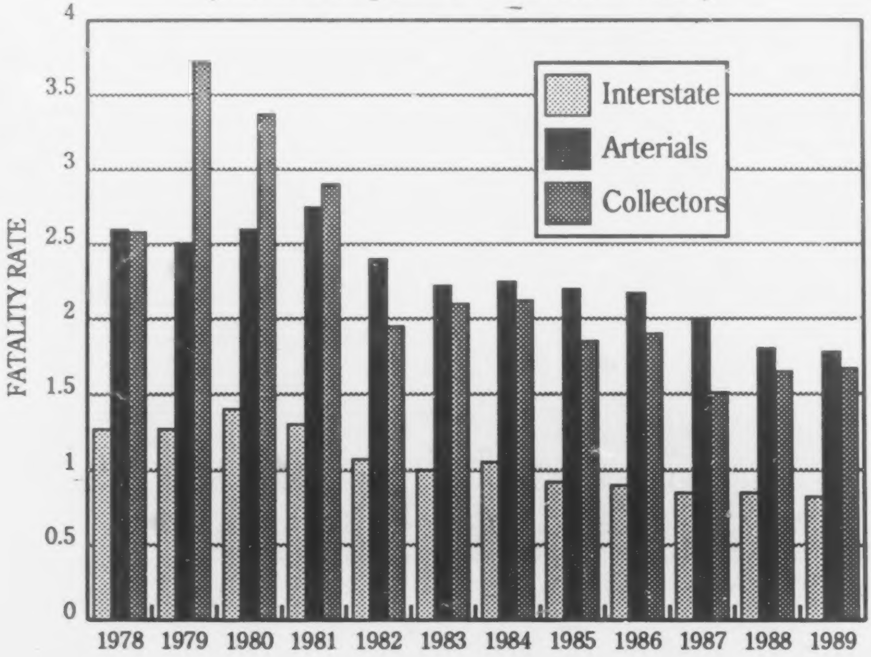


Exhibit 3-20
Rural Highway Fatality Rates
(Fatalities per 100 million VMT)



Source: Fatal Accident Reporting System Annual Reports, 1978 – 1988

Exhibit 3-21
Urban Highway Fatality Rates
(Fatalities per 100 million VMT)



Source: Fatal Accident Reporting System Annual Reports, 1978 – 1988

Conditions on the Federal-Aid System

Condition and performance information has been presented for the highway functional systems. However, a brief account of conditions on the Federal-aid Systems is given to provide an association with these historic systems which align in varying degrees with the functional systems.

Exhibits 3-22 through 3-24 contain the estimated distributions across Federal-aid categories for pavement condition, alignment adequacy, and lane width. It should be noted that these estimates are based on a sample that was not specifically drawn to represent Federal-aid systems. Also, the sample does not contain any highways functionally classified as local highways, which make up about 89 percent of the non-Federal-aid mileage. Therefore, the conditions of non-Federal-aid highways shown here are representative of only a portion of highways not included on the Federal-aid systems. The distributions across Federal-aid systems are similar to those previously described for the functional systems in that the better conditions are found on the higher order systems.

Exhibit 3-22
1989 Mileage by Federal-Aid System and Pavement Condition (in percent)

	Pavement Serviceability Ratings*			
Federal-Aid System	0.0 – 2.0** (Poor)	2.1 – 3.4** (Fair)	3.5 – 5.0 (Good)	Unpaved
Rural				
Interstate	9.9	32.7	57.4	0.0
Other Primary	5.0	47.4	47.5	0.1
Secondary	8.8	44.6	35.8	10.8
Non-Federal-aid	10.1	35.4	22.1	32.4
Urban				
Interstate	10.1	33.5	56.4	0.0
Other Primary	5.0	50.8	44.2	0.0
Urban	8.8	51.3	39.1	0.8
Non-Federal-aid	13.9	54.8	30.3	1.0

*Estimate only. Based on HPMS expanded sample data not specifically designed for Federal-aid categorizations. Non Federal-aid figures for this table do not include roads functionally classified as "local." Only roads classified as "collector" or higher are included in non Federal-aid mileage.

**For Interstate highways, the "poor" range is 0.0 – 2.5 and the "fair" range is 2.6 – 3.4.

For an explanation of PSR, refer to Figure 4-1.

Source: 1989 HPMS Master Dataset

Exhibit 3-23
Rural Highway Mileage by Alignment Adequacy and Federal-Aid System (in percent)

	Horizontal Alignment Adequacy Ratings			
Federal-Aid System	Code 1	Code 2	Code 3	Code 4
Interstate	94.4	3.9	1.1	0.6
Other Primary	70.9	12.7	8.2	8.2
Secondary	50.4	22.0	16.9	10.7
Non-Federal-Aid	40.1	25.2	19.6	15.1
	Vertical Alignment Adequacy Ratings			
Interstate	92.2	6.3	0.2	1.3
Other Primary	60.3	29.9	5.7	4.1
Secondary	47.6	32.4	13.8	6.2
Non-Federal-Aid	43.1	34.1	15.4	7.4

Code 1	All grades/curves meet appropriate design standards.
Code 2	Some grades/curves are below design standards for new construction, but curves can be negotiated safely at prevailing speed limits. Truck speed is not substantially affected.
Code 3	Infrequent curves impair sight distance or affect truck speed. Infrequent curves may have reduced speed limits for safety purposes.
Code 4	Frequent grades that impair sight distance or severely affect truck speeds. General curves are unsafe and/or uncomfortable at prevailing speed limit, or the speed limit is severely restricted due to the design speeds of the curves.
Note:	Paved mileage only. Sections for which no alignment data were supplied are treated as Code 2. Mileage is based on HPMS sample data which do not include roads functionally classified as "local." Non Federal-aid system roads are functionally classified as "collector" or higher.

Source: 1989 HPMS Master Dataset

Exhibit 3-24
Highway Mileage by Lane Width and Federal-Aid System (in percent)

Federal-Aid System	Less Than 9 Feet	9 Feet	10 Feet	11 Feet	12 Feet or More
Rural					
Interstate	0.0	0.0	0.0	0.1	99.9
Other Primary	0.2	1.8	8.8	16.2	73.0
Secondary	1.8	9.5	32.3	23.9	32.5
Non-Federal-Aid	8.5	22.9	34.9	16.6	17.1
Urban					
Interstate	0.0	0.0	0.0	0.1	99.9
Other Primary	0.1	0.6	7.1	10.4	81.8
Urban	1.6	5.3	18.5	16.4	58.2
Non-Federal-Aid	1.6	6.1	20.1	12.8	59.4

Source: 1989 HPMS Master Dataset

Chapter 4
Highway and Bridge Investment Analyses, 1990–2009

Summary

- The average rate of growth in highway travel is expected to be 2.5 percent annually through 2009. This forecast is below actual historic travel growth levels, which have exceeded 3.0 percent for most 5-year periods since 1945. At a 2.5 percent average annual rate, travel will increase by about 65 percent from 1990 to 2009.

- Pavement conditions currently exhibit a reduced and stabilized percentage of pavement in poor conditions, but with decreasing overall condition averages. Current service levels exhibit high levels of congestion in urban areas, especially on the highly used upper level systems.

- Future investment requirements have been estimated for two scenarios: *Improving 1989 Conditions and Performance* and *Maintaining 1989 Conditions and Performance*. Highway investments are simulated when pavement, geometric, safety or service-related conditions have deteriorated below prescribed minimum condition standards. Bridge investment estimates are simulated when a bridge either can not safely carry the size and weight of vehicles expected to use the bridge and/or when the width of a bridge is an impediment to smooth and safe traffic flow.

No policy priorities regarding strategic importance of individual facilities or classes of highway are assumed in determining scenario costs, nor have institutional constraints to highway and bridge improvements, such as fiscal capacity or air quality considerations in non-attainment areas. The assessment procedures treat individual elements of highway systems and bridges as discrete elements of infrastructure that provide service and require maintenance and repair to ensure their serviceability and physical integrity. The estimates represent investment requirements to achieve known objectives for the entire highway system. Certain policy-oriented assumptions have been made, however, such as reduced rates of travel growth in highly congested urban areas, the application of rigorous supply and demand management strategies prior to estimation of construction costs, and a constraint on the amount of new highway capacity in large urban areas.

The scenarios are thus not intended to represent comprehensive alternative national investment policies since, in actual practice, States would apply priorities to focus improvements on selected facilities. Nonetheless, they provide general financial and performance benchmarks and a basis for development and evaluation of policy and program options.

The design standards and simulated improvement strategies that determine the type of improvement made when a highway or bridge deficiency is identified vary according to the system on which the facility is located and follow State programming practices. The amount of highway capacity simulated by the procedure is that necessary to support traffic growth 20 years into the future. The type of pavement improvement simulated considers pavement requirements 5 to 7 years into the future.

Highway Investment Requirements

- *The cost of repairing all* backlog *highway deficiencies that existed on arterials and collectors on December 31, 1989, is approximately $400 billion.* This could increase to as high as $575 billion if necessary improvements are delayed.

- *The average annual cost to repair all backlog deficiencies and keep all existing arterials and collectors above the specified minimum condition and performance standards through 2009, referred to as the* Improve 1989 Condition and Performance *scenario, ranges from* $60.4 to $68.4 billion, depending on the number of years taken to repair backlog deficiencies. This scenario would require an average investment of about 3.2 cents per vehicle mile of travel, compared to approximately 1.2 cents, or approximately $22 billion, invested in 1989 *for similar capital improvements on the same highways*. If travel increases at the average annual rate of 3.0 percent, a level more consistent with historic travel growth, this scenario would cost about $74 billion annually.

- *The average annual cost to* Maintain 1989 Condition and Performance *on existing arterials and collectors through 2009, is estimated at* $33.1 billion. This scenario would require an average investment of about 1.8 cents per vehicle mile of travel, compared to about 1.2 cents, or about $22 billion, invested in 1989 for similar capital improvements on the same highways. If travel increases at the average annual rate of 3.0 percent, this scenario would cost about $38.8 billion annually.

  Both of these estimates include an estimated $3.4 billion annual capital savings from an aggressive traffic management program.

- $4.0 billion annually is required to repair roads functionally classified as local roads and to build new local roads to support urban/suburban growth.

- $30 million annually is required to meet defense specific needs on the STRAHNET.

- $4.5 billion is required annually to provide additional arterial and collector capacity in growing suburban areas to accommodate the mobility requirements of population and employment change and growth.

Bridge Investment Requirements

- *The cost of repairing all* backlog *bridge deficiencies that existed on June 30, 1990, is approximately $91 billion.* This could increase to as high as $131 billion if improvements are delayed.

- *Between $6 and $8.5 billion annually is required to eliminate all backlog and accruing bridge deficiencies through 2009,* depending on the treatment of the backlog.

- *The cost to maintain current overall bridge conditions is estimated at $4.2 billion annually.*

Introduction

This chapter estimates capital investment requirements from all sources for the period 1990-2009, based on maintaining certain minimum engineering condition and performance standards for all highways and bridges. The chapter addresses capital requirements to repair deficient pavement, to eliminate unsafe conditions, and to add the capacity necessary either to maintain or to enhance highway system service levels. Estimates are also included for repairing bridge deficiencies.

The investment scenarios represented are not intended to represent alternative national investment policies. They are based on standards applied uniformly nationwide without consideration of the relative importance or strategic value of specific highway or bridge facilities, regional variation or other policy considerations. However, the estimates do provide benchmarks for developing policy and program options for addressing investment requirements and for evaluating individual proposals.

Both analytic and strategy modifications have been introduced to the report in response to congressional request. First, forecasting procedures have been altered to simulate the route diversion and peak-spreading that more accurately reflect actual traffic behavior under congested conditions and make more efficient use of existing capacity. Second, strategy responses have been broadened to more realistically depict actual investment practices which include options that are both more and less capital intensive than conventional highway widening to which the previous reports were confined.

Highway and Bridge Investment Analysis Procedures

The highway investment estimates reported here were developed using the Highway Performance Monitoring System (HPMS) Analytical Process. Bridge estimates were made using the Bridge Needs and Investment Process (BNIP). Both of these engineering based investment simulation model packages use procedures that do the following:

(1) Simulate the effects of future vehicle travel and normal weathering on highways and bridges.

- For this report, a 2.5 percent average annual highway travel growth rate is assumed in keeping with recent estimates of driver and mileage saturation, although summary estimates are included for an average annual growth rate of 3.0 percent.

(2) Apply minimum engineering standards to determine which facilities will become deficient.

- Minimum acceptable pavement condition standards vary from PSR 2.0 to 3.2 for the various functional highway systems, in accordance with actual State highway agency practices.
- A volume to capacity ration (V/C) of between 0.8 and 0.95 is used as the threshold at which capacity improvements are simulated, varying by functional system. Capacity improvements are not simulated on higher design facilities until a V/C of 0.95 is surpassed, equivalent to level of service E, or worse.
- Various other minimum condition standards are used to assess geometric and cross-sectional deficiencies.

(3) Determine what type of improvement is most cost-effective to remedy the engineering deficiency(ies).

- The type of improvement simulated varies with the minimum condition standard(s) that has been exceeded.

(4) Calculate how much the repairs or highway improvements will cost.

- Unit costs are national averages modified to reflect State construction cost differentials.

The selection of assumptions determines the timing of deficiencies and improvements. A more detailed, non-technical explanation of the procedures can be found at the end of this chapter. Technical reports describing the HPMS database and sampling system and the analytical procedures are available from the FHWA.

Improvements to the Report

Investment analysis has been an evolutionary process since the development of the Highway Performance Monitoring System (HPMS) Analytical Process in the late 1970's. Each succeeding report in this series has included ***procedural improvements*** to this analytical process to more accurately simulate highway and bridge investment requirements. Each report has introduced analytical methods so as to expand the ***report coverage*** to include all elements of highway and bridge requirements. This report capitalizes on continuing improvement activities as described below.

Procedural Improvements

As highway travel increases faster than capacity, congestion in the morning and afternoon peak periods extends for longer periods of time and in more locations. As a result, high traffic volumes occur over more hours of the day and congestion spreads from major facilities to a larger number of parallel facilities that can serve the same trips. Together, these changes in travel behavior make more intensive and efficient use of available highway capacity.

To reflect this phenomenon and reduce the tendency of the simulation to "over-invest," two significant improvements in system and travel responses to congestion have been introduced into the simulation models. These are:

(1) *simulation of peak spreading*, through the reduction in the percent of future daily travel that is expected to occur during peak-periods, and

(2) *evaluation of the potential for route diversion* during periods of high congestion to parallel facilities that have available capacity.

An analysis of the potential of congestion management to reduce the investment requirements associated with future traffic growth is also included. The potential savings in required future highway investment from the application of a coordinated operations and management strategy has been estimated and is described below. The potential savings that might be attributable to such a strategy have been incorporated, by functional system, into the investment requirements.

These changes produce more realistic assessments of traffic patterns and related investment requirements for the congested conditions that are widespread today.

Improvements have also been made to the bridge deficiency and investment estimate procedures. These changes eliminate duplication in the highway and bridge investment estimates and more accurately simulate the impacts of certain emergency vehicles on bridge deterioration. A discussion of those changes is included in the section on bridge investment.

Expanded Investment Requirements Coverage

In 1989, the report was accompanied by congressional requests that a "broader level" of investments be considered, including those at both higher and lower levels of capital intensity. Exhibit 4-1 summarizes the types of highway and bridge improvements highway agencies typically address, and indicate which have been included in this report compared with previous versions. This exhibit also includes estimated 1989 expenditures by all units of government for these broad improvement categories. Requirements not previously included in the report series include highway capacity expansions on new rights-of-way to address travel demand in and around larger urbanized areas, highway and bridge infrastructure in expanding suburban areas, local roads, and defense requirements.

As a result of the addition of these items, the report now contains investment estimates covering most improvement types included in State and local programs. *While earlier reports included about 67 percent of total spending requirements, this report covers an estimated 85-90 percent of requirements.* The only major item not included is the cost of roads for economic development purposes. State policies and priorities for these types of improvements vary significantly, thus far precluding the development of a rigorous procedure for estimating such requirements nationwide. Comparisons of required investments included in this report with actual State highway and bridge program activities should consider these differences in coverage.

Because of the extensive changes in the procedures used in identifying deficiencies, particularly the incorporation of procedures to reflect peak spreading, results from this report can not and should not be directly compared with previous versions of the report. Although the investment strategies contained in this and earlier versions use the same, or similar, names, the actual magnitude and extent of improvements and the methods used in arriving at the estimates are significantly different.

New Capacity to Meet Travel Growth Requirements. Growth in travel is rapidly outstripping available highway capacity. To accommodate capacity demands, States are commonly employing strategies beyond the simple addition of lanes to existing facilities within existing rights-of-way. Increasingly they are constructing highways on new, often parallel alignments, within corridors and/or enhancing capacity on existing roads through grade-separation structures (elevated or depressed sections) or via acquisition of more costly rights-of-way.

Projects of this nature are found in virtually every expanding major metropolitan area and include such projects as I-75/85 through Atlanta, I-95 connecting Miami and Ft. Lauderdale, the Dan Ryan Expressway in Chicago,

Exhibit 4-1
Program and Report Coverage

Highway and Bridge Improvements Addressed by State and Local Highway Agencies	1989 Report	1991 Report	Estimated 1989 Capital Expenditures (billions)
Pavement and safety improvements to arterials and collectors	Yes	Yes	$6.7
Capacity additions to existing arterials and collectors	Some	Yes	$7.1
New arterial and collector highway and bridge construction	No	Some	$7.8
Capital improvements to local functional class, including new construction	No	Yes	$5.4
Bridge replacement and rehabilitation on arterials and collectors	Yes	Yes	$4.6
Defense highway and bridge requirements	No	Yes	Included elsewhere
Operational improvements	No	Yes	$1.7
Total			$33.3

the North Central Expressway in Dallas, the East-West Freeway in Houston, the Papago Freeway in Phoenix, I-5 in Seattle, the Santa Anna Freeway in Orange County, and many others.

Previous reports have not included costs for these types of improvements. Investment estimates have been limited to those capacity additions that could be accomplished through widening existing facilities using an established average per lane-mile cost. The 1989 report noted that the investment requirements reported at that time were therefore understated and did not present the actual "cost to maintain current conditions" (despite the implication of the name applied to that estimate) since the cost of all required capacity was not included.

In response to the congressional request that the "real" cost of actually preserving existing conditions and performance be assessed, and in recognition of actual State practice, this report contains a more complete array of investment types including those at both higher and lower capital intensity. New capacity supplied on new rights-of-way or through "higher than average" cost lane additions on existing rights-of-way have been included using actual 1989 unit cost data.

However, such higher cost lane additions have been limited ***such that the combination of existing and new capacity in a given corridor may not exceed 12 lanes.*** Any travel demand that would require capacity additions above the 12 lane limit is reported as "unmet lane-miles of demand" and is not included in the investment requirements estimates. Higher cost lane-miles total less than 4 percent of the *total* lane requirements to meet minimum performance standards, but about 35 percent of the *added* capacity required to meet expected travel demand.

Unit costs for these new rights-of-way or grade separation additions were developed from a weighted average of 1989 Federal-aid project records for major new highway capacity additions in and near larger urbanized areas. Enhancements of this nature increased costs up to 40 percent above the average costs used in the simulation procedure, adding an average increment of $900,000 to the $1.4 million to $3.7 million per lane-mile range for "average" facility expansion. Since the report is national in scope, and not project specific, no distinction is made between the addition of new lanes to existing roads or the construction of highways on new alignment. The intent is to estimate the costs that would be incurred, and not to specify how such improvements would be made on a case by case basis.

Suburban Expansion. Previous reports included the capacity requirements for accommodating urban and rural demand separately. However, no provision was made for the types of investments actually being made to accommodate the rapidly increasing suburban travel demand that characterize growing metropolitan areas. This report includes an estimate for new highway capacity that must be added in areas currently considered rural that are expected to be urban in character by the year 2009. These estimates are reported independently, and are included under the category ***Urban/Suburban*** investment requirements in the summary table (Exhibit 4-16). Rural estimates have been reduced accordingly, in order to avoid double counting.

Capital Requirements for Local Roads. Capital investment on roads functionally classified as local roads is a responsibility of State and local governments. Previous reports have not included estimates of future capital investment requirements for the approximately 2.6 million miles of local roads, because the HPMS database does not contain condition and performance information for these facilities. This report includes a preliminary estimate of future local road capital requirements based on a 1987 survey conducted by the U.S. Department of Agriculture on the physical conditions of local roads and an assessment of current capital costs incurred by municipal and county governments.

Defense Highway Requirements. Approximately 60,000 miles of Interstate and other arterial highways comprise the Strategic Highway Defense Network, or STRAHNET. For purposes of military mobilization, these highways have been accorded certain design specifications in order to accommodate large and heavy military vehicles. This report includes an estimate of the capital requirements necessary to achieve those design specifications, above and beyond what would normally be required to accommodate nonmilitary traffic.

Congestion Management. New construction is not the only option that may be considered in combatting increasing congestion. In recent years, State highway agencies have emphasized systems operations and management as a means of increasing highway capacity through maximizing the efficiency of existing facilities. In addition, several urbanized areas have implemented traffic management programs to reduce or more effectively handle peak period traffic. These efforts have been in response to increasing social and environmental concerns, to the problem of siting new facilities, and to the cost of new highway construction, particularly in higher density and environmentally sensitive areas.

In this report, prototypical strategies for both improved traffic operations and management on the supply side, and increased ridesharing and transit use on the demand side, have been applied in determining the remaining highway travel demand for which capital investment levels are determined. While the report does not indicate which of these traffic management strategies(ies) are the most appropriate, it does estimate increased system throughput and potential savings in new highway capacity that could be expected as a result of a systematic nationwide application of a rigorous operations and management strategy. It must be noted that the cost reduction impacts represent an aggressive upper limit of financial impact since such strategies are currently limited to a small proportion of urban areas. The investment impacts of traffic management strategies and increased transit usage are reported separately from the construction cost estimates and are factored into the individual functional system investment requirements in the summary table (Exhibit 4-12).

Highway Investment Requirements, 1990-2009

This report contains two estimates of investment requirements, an ***Improve 1989 Conditions and Performance*** scenario and a ***Maintain 1989 Conditions and Performance*** scenario. As indicated above, neither scenarios represents a policy strategy since they are based on standards applied uniformly nationwide without consideration of the relative importance or strategic value of specific facilities, regional variation, or other policy considerations.

- The *Improve Conditions and Performance* scenario provides an estimate of the costs associated with achieving and maintaining predefined minimum condition standards for physical conditions and performance. These standards reflect high levels of roadway safety through the elimination of unsafe highway curves and grades and narrow lane widths, efficient life-cycle costs for physical preservation through a sustained cost-effective level of pavement condition, and more productive peak-period service levels just above stop-and-go conditions. This scenario would improve conditions and performance across all functional systems on a uniform basis nationwide, urban and rural, even as travel demand increases, except in larger urbanized areas, where performance cannot be significantly improved because of capacity limitations.

  This scenario involves no priorities regarding cost-effectiveness and is not intended to represent an optimum recommended investment strategy. For example, it includes pavement improvements on lower volume roads and substantial urban capacity additions in high cost areas, improvements that might never be made be made because of siting problems or restrained highway budgets. However, the scenario provides a framework for policy development through establishing a measure of the total capital costs of providing a desirable level of highway and bridge infrastructure on all facilities, using good engineering practices, assuming a future travel demand of 2.5 percent annually.

- The *Maintain Current Overall Conditions and Performance* scenario provides an estimate of the cost of maintaining both current overall physical conditions and current levels of performance as traffic increases over the twenty year analysis period. While current physical conditions vary widely, average conditions are rated as "fair," with about half of the Nation's arterial and collector pavements rated in "good" or "high fair" condition and the other half in "poor" or "low fair" condition. Current levels of performance include about 70 percent of urban Interstate peak-period travel and 43 percent of other urban arterial peak-period travel occurring under congested or highly congested conditions. As with the "Improve" scenario, overall system performance would not be maintained in the largest urbanized areas, assuming the amount of travel increase expected, even with an aggressive traffic management program. However, under the funding levels associated with this scenario, States could improve conditions of the higher priority routes.

Together, the two scenarios, by simulating the costs associated with both today's conditions and a consensus minimum standard target, provide benchmarks against which to consider current investment strategies and policies. While the scenarios invest on a rigorous systemwide basis without application of policy-based priorities or fiscal constraints, they provide the basis for examining investment implications on a functional class basis, for urban vs. rural comparisons, and for determining the cost implications of various combinations of conditions and performance.

Each investment scenario is calculated using the minimum conditions standards to estimate *backlog* and *accruing* deficiencies. A backlog requirement is the cost of fixing highway deficiencies that existed on December 31, 1989 for highways and June 30, 1990 for bridges. An accruing requirement refers to the cost of repairing deficiencies that will occur in the future as the result of travel demand and system deterioration attributable to traffic loads and normal weathering.

A separate estimate of the investment requirements associated with the backlog deficiencies alone — without the accruing deficiencies — is also provided as a point of comparison for the two scenarios.

Each investment scenario treats the backlog of highway deficiencies differently. Under the *Improve Conditions and Performance* scenario, backlog deficiencies are treated separately, and eliminated over the course of the 1990-2009 analysis period. For this reason, a separate discussion of backlog investment requirements and the added cost of deferring improvements is included under the *Improve Conditions and Performance* scenario. Under the *Maintain Conditions and Performance* scenario, the overall size of the backlog is, by definition, constant. Under this scenario, the added cost of delaying highway capital investment is not separately discussed.

Both scenarios invest in improvement strategies to meet their objectives each year as travel demand grows at the specified rate. Therefore, there is an any given time, including the end of the analysis period, a residual system value associated with meeting future pavement and capacity requirements.

Point of Departure: Today's Conditions and Performance

The points of departure for the determination of investment requirements associated with the two scenarios are current highway conditions and traffic volumes and expected future traffic growth. Growth in future travel determines future levels of service against which capacity increases are simulated and also provides the basis (together with aging) for simulating the physical deterioration against which physical improvements are made and investment costs accumulated.

The estimates of future traffic levels are based on State-supplied HPMS data submittals. Since previous travel forecasts have consistently underestimated future travel, the sensitivity of investment estimates assuming a 3.0 percent average annual growth rate have been included for comparison.

The "Improve 1989 Condition and Performance" Scenario

The average annual cost to repair all backlog deficiencies and keep arterials and collectors above the specific minimum condition and performance level standards through 2009, referred to as the Improve 1989 Condition and Performance *scenario, ranges from $60.4 to $68.4 billion, depending on the number of years taken to repair backlog deficiencies.* This scenario would require an average investment of about 3.2 cents per vehicle mile of travel, compared to about 1.2 cents invested in 1989 for similar capital improvements on the same highways.

Investment requirements are directly related to travel growth between 1990 and 2009. If travel increases at the average annual rate of 3.0 percent, this scenario would cost about $74 billion annually.

Both of these estimates include the capital savings of an aggressive traffic management program, estimated to reduce construction costs by about $3.4 billion annually.

The Backlog Component of the "Improve 1989 Conditions and Performance" Scenario

The investment requirements of this scenario can be divided into its backlog and accruing components. The backlog component represents the cost of bringing the current system up *to at least* today's minimum standards from its existing conditions and performance status.

As of December 31, 1989, the cost of eliminating the backlog of highway deficiencies was estimated at $400 billion for all existing arterials and collectors. Exhibits 4-2 and 4-3 present backlog deficiency costs from two perspectives: total backlog costs, and backlog costs per vehicle-mile of travel.

The pavement and capacity costs shown for backlog (as well as accruing deficiencies) are based on cost-effective civil engineering practices. This means that the pavement improvements are designed to support requirements 5 to 7 years into the future, and capacity costs reflect adequate construction to support a 20-year design. These design standards minimize the life cycle costs of highway construction and maintenance and reduce the amount of vehicle delay and hazard that may be imposed by highway construction and repair.

Approximately 28 percent of the backlog is pavement cost; the remaining 72 percent is the cost of adding capacity to restore system performance to or above the level of service defined by the minimum condition standards. (When new lanes are added to a highway facility, or the existing lanes are widened to increase capacity, the remaining lanes are resurfaced so that no "seam" exists between the existing and the new pavement. The cost of this resurfacing, which typically would be required whether or not a capacity improvement was simulated, is included in the 28/72 ratio as a pavement, rather than a capacity cost.)

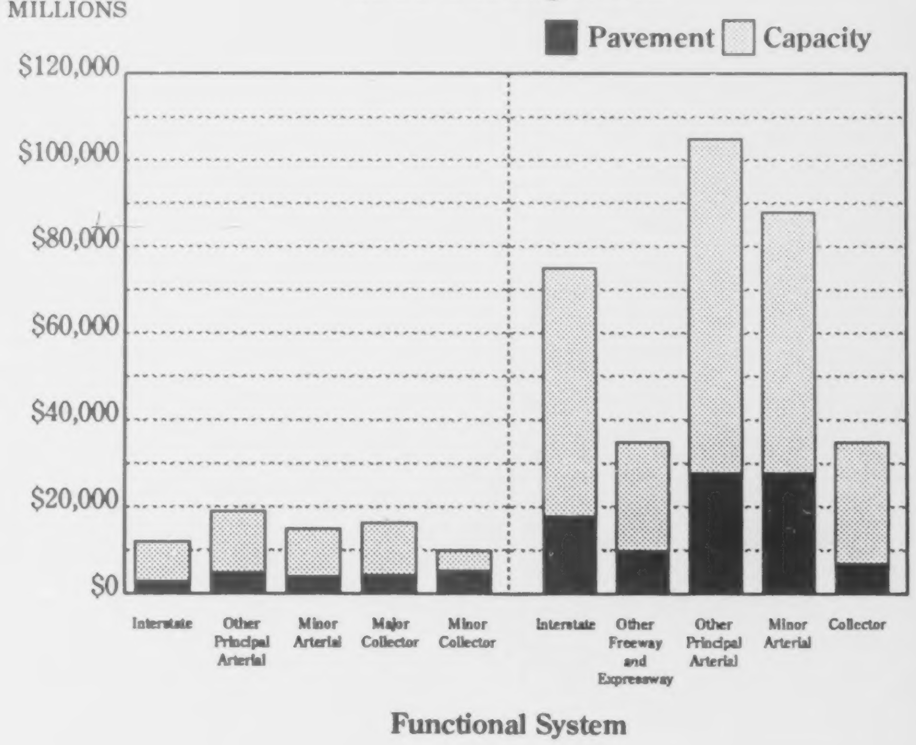
Backlog requirements in urban areas are significantly higher than those in rural areas, mostly due to inadequate highway capacity. Backlog deficiencies are fairly evenly distributed among the functional highway systems. Higher order systems have higher amounts of capacity backlog deficiencies, while lower order systems, both urban and rural, tend to have relatively higher amounts of safety and pavement related backlog deficiencies.

Historically, total actual investment for the types of improvements discussed here has always been less than what would be required to maintain minimum conditions standards. Although the amount of pavements rated in poor condition has stabilized over the last two years, the *average* condition of roads has deteriorated. Consequently, the backlog of needed improvements has increased. ***The cost of deferring improvements on roads that were identified as deficient in 1987 and remained deficient in 1989 added $8 to $12 billion to the backlog estimate in 1989.*** Future deferred costs could be as high as $8 billion annually, depending on the timeliness of addressing backlog deficiencies. Backlog and cost deferral is discussed in greater detail later in this chapter.

Backlog Plus Accruing

Exhibit 4-4 presents *Improve 1989 Condition and Performance* investment requirements for the period 1990-2009. Only those roads that fall below the minimum thresholds of condition and performance have an improvement cost included in this estimate. The exhibit shows total 20-year investment requirements categorized as pavement and capacity improvements, backlog and accru-

Exhibit 4-2
1989 Backlog Needs

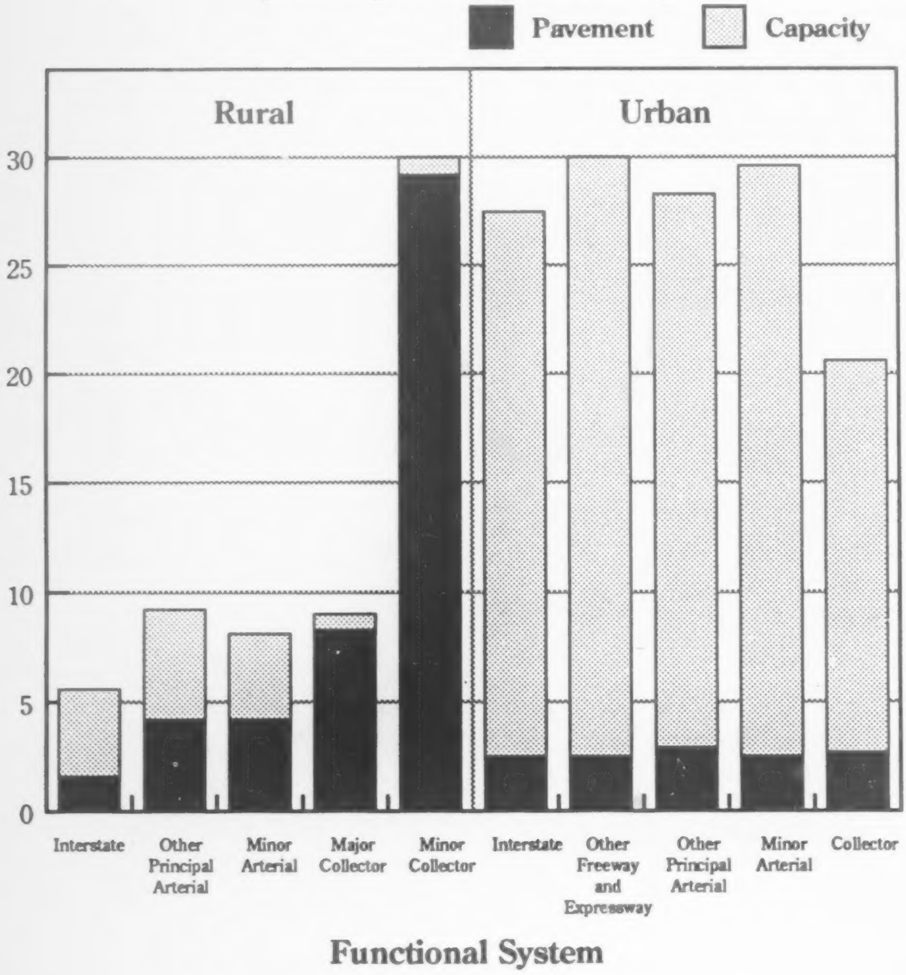


ing, with annualized totals. The annualized total is the 20-year total divided equally.

Under this scenario, approximately 68 percent of total investment would occur in urban areas. Capacity improvements would account for about 72 percent of urban investment, and 63 percent of total investment. Between 29 and 33 percent of total investment would be the cost of eliminating the backlog of deficiencies. The range for eliminating the backlog represents the potential added capital cost of delaying improvements beyond the point at which they are identified.

Exhibit 4-5 shows the current and future number of lane-miles of highway facility by functional class in both rural and urban areas under this investment scenario. The 2009 values are shown in two columns: (1) lane-mile requirements

Exhibit 4-3
1989 Backlog Deficiency Costs
(cents per unit of travel)



for expansion capacity, and (2) lane-mile requirements for new right-of-way/higher cost capacity. No facility is simulated to have more than a total of 12 lanes of existing plus new capacity combined.

System Conditions and Performance Impacts

The *Improve 1989 Conditions and Performance* scenario results in only modest improvements in overall pavement conditions on the higher functional systems since between 85 and 90 percent of these pavements already meet minimum standards. On all systems, the minimum standards scenario would increase the average pavement condition to what could be termed a "high fair" category, with the mean approaching a PSR of from 3.3 to 3.5. PSR values of 4.0 or greater reflect pavements in good to excellent condition. A rating of between 3.3 and 3.5 represents a condition where pavements, on average, have between 8 and 12 years of remaining design life.

However, as shown in Exhibit 4-6, the *Improve 1989 Conditions and Performance* scenario would significantly improve system performance on rural and many urban highways, supporting at least a minimum level of service E during the daily peak-period of demand. Level of service E is the point at which congestion begins to seriously impede traffic flow, with intermittent stop-and-go

Exhibit 4-4
Improve 1989 Conditions and Performance
2.5% VMT Growth Rate
(billions of 1989 dollars)

Improvement Type	Capacity	Pavement	Total
Rural			
Interstate	38.8	26.1	64.9
Other Principal Arterial	45.2	28.9	74.1
Minor Arterial	31.2	43.1	74.3
Major Collector	30.6	77.4	108.0
Minor Collector	15.2	45.0	60.2
Subtotal	161.0	220.5	381.5
Urban			
Interstate	169.0	45.2	214.2
Other Freeway & Expressway	68.2	16.8	85.0
Other Principal Arterial	176.8	60.3	237.1
Minor Arterial	127.6	56.5	184.1
Collector	56.6	49.0	105.6
Subtotal	598.2	227.8	826.0
Total	759.2	448.3	1,207.5
Annual	38.0	22.4	60.4

conditions, increased delay, fuel consumption, vehicle operating cost, and vehicle emissions.

This scenario would not only eliminate most highly congested conditions; it would also improve performance on high-volume highways soon to be congested given the projected VMT growth rate. In effect, this investment scenario builds a "reserve" of capacity to accommodate future travel at the minimum conditions standard levels of service over a twenty year period.

The scenario does not imply system perfection. Conditions and performance would be superior to today, but substantially below the design and performance standards expected of new, or nearly new roads. No section of road would be in "poor" condition, as defined by the minimum condition standards used to identify deficiencies. Even at this investment level, large segments of the highway system would still exhibit physical and operating characteristics that

Exhibit 4-5
Total Lane-Mile Requirements – Improve Conditions (2.5% Annual VMT Growth Rate)

	2009 Lane-Miles Required			
Functional System	1989	Expansion Capacity (1989 facilities)	New ROW Higher Cost Capacity	Total
Rural				
Interstate	134,969	184,442	4,987	189,429
Other Principal Arterial – High	74,095	140,626	9,575	150,201
Other Principal Arterial – Low	131,723	87,333	443	87,776
Minor Arterial	308,266	327,089	7,562	334,651
Major Collector	880,650	892,352	4,739	897,091
Minor Collector	586,998	589,558	300	589,858
Subtotal	2,116,701	2,221,400	27,606	2,249,006
Urban				
Interstate	61,854	81,718	11,522	93,240
Other Freeway & Expressway	33,739	43,790	6,208	49,998
Other Principal	170,977	210,283	35,710	245,993
Minor Arterial	188,218	226,132	31,176	257,308
Collector	167,699	186,744	15,635	202,379
Subtotal	622,487	748,667	100,251	848,918
Total	2,739,188	2,970,067	127,857	3,097,924

Note: Maximum number of lanes = 12. High principal arterials carry greater than 6,000 vehicles per day. Low principal arterials carry less than or equal to 6,000 vehicles per day.

are indicative of a system only in fair condition, although above the minimum thresholds. This is because the minimum condition standards are substantially below full design standards for new roads.

The capacity increases simulated under the *Improve 1989 Conditions and Performance* scenario occur within all functional systems, with most concentrated in the fully and partially access controlled facilities. The distribution in required capacity is in keeping with the continuing shift in travel demand from non-access controlled to fully and partially access controlled facilities that normally parallels population growth in and adjacent to urban areas.

The travel forecasts imply a continuation of this trend in demand for access controlled facilities, but with a higher share spreading beyond the Interstate to other principal arterials that are generally less congested but serve essentially the same functions as the Interstate and other freeways and expressways. This shift leads to more efficient use of available highway capacity during the peak period. It also expands the congestion currently found mostly on limited access facilities to other roads in many urban areas.

As indicated in Exhibit 4-5, this scenario projects about a 50 percent increase in urban Interstate and freeway lane-miles and a 44 percent increase in other urban principal arterial lane-miles. It is unlikely that capacity improvements of this magnitude would be cost-effective or feasible because of dislocation, air quality, and noise effects.

Exhibit 4-6
System Performance Impacts of the Improve Conditions and Performance Scenario

System	1989		2009	
	Capacity (V/C > 0.8)	Pavement (Poor)	Capacity (V/C > 0.8)	Pavement (Poor)
Rural				
Interstate	23%	9%	15%	0%
Other Principal Arterial	9%	5%	5%	0%
Minor Arterial	6%	5%	1%	0%
Major Collector	4%	10%	0%	0%
Minor Collector	1%	12%	0%	0%
Urban				
Interstate	70%	10%	45%	0%
Other Freeway & Expressway	60%	3%	35%	0%
Other Principal Arterial	43%	6%	25%	0%
Minor Arterial	34%	9%	20%	0%
Collector	21%	18%	10%	0%

In future years, as such excess capacity is absorbed through traffic diversion, congestion will begin to appear on more facilities, and more vehicles will be subjected to the added costs imposed by congestion. This future perspective is in keeping with the increased duration of congestion discussed in the previous chapter on condition and performance.

Unmet Demand

The *Improve Conditions and Performance* scenario would still leave about 49,000 lane-miles of unmet demand in future years, because of the 12-lane constraint assumed for the analysis. Approximately 50 percent of this unmet demand would be concentrated in nine of the Nation's largest urbanized areas. The remaining 50 percent would be distributed throughout the Nation, primarily in urbanized areas of at least 500,000 population.

These are areas where expected peak-hour travel demand cannot be accommodated within the 12-lane limit even at level of service E, through the addition of new highway capacity, whether through added lane-miles to existing highways, higher cost approaches such as grade separations, or the construction of new alignment facilities within the same travel corridor.

Since diversion, reasonable new capacity and aggressive traffic management are all incorporated into the traffic level simulation, such areas may experience significant increases in congestion in coming decades, if traffic continues to grow at expected levels.

The "Maintain 1989 Condition and Performance" Scenario

The average annual cost to Maintain Condition and Performance on existing arterials and collectors through 2009, is estimated at $33.1 billion. This scenario would require an average investment of about 1.8 cents per vehicle mile of travel, compared to about 1.2 cents invested in 1989 for similar capital improvements on the same highways.

If travel increases at the average annual rate of 3.0 percent, this scenario would cost about $38.8 billion annually. Both of these estimates include the estimated $3.4 billion capital savings of an aggressive traffic management program.

Exhibit 4-7 shows investments required to *Maintain Condition and Performance* for each functional system of highway. No backlog is shown because the *Maintain Condition and Performance* scenario does not treat backlog deficiencies as a separate entity.

These cost estimates are higher than similar estimates contained in the 1989 report because of inflation, the inclusion of the higher than average cost lane-miles required to actually maintain performance, and the general deterioration in system performance over the last two years. Indeed, the estimate simply to maintain these levels has been increasing while the level of condition and performance to be maintained has been declining. This is because total investment has not been sufficient to maintain current conditions and performance.

Under this scenario, approximately 55 percent of total investment would occur in urban areas, compared to about two-thirds under the *Improve Conditions* scenario. Capacity improvements would account for less than 60 percent of urban investment, compared to over 70 percent under the *Improve Conditions* scenario. Capacity would account for about half of total investment, compared to slightly over 60 percent under the *Improve Conditions* scenario.

System Performance Impacts

Under the *Maintain Conditions and Performance* scenario, the backlog would remain essentially the same over the 20-year analysis period. Current physical conditions include about 630,000 miles of roadway that have poor, or approaching poor, conditions including about 11 percent of Interstate System mileage. System performance would be maintained at its current levels. This means that about 70 percent of peak-hour travel on the urban Interstate System would continue to experience level of service E or worse. This is the point at which traffic flow becomes unstable, with rapidly increasing stop-and-go conditions, increased fuel consumption, delay, and vehicle emissions.

The makeup of the backlog would change, however, as selected improvements were made on some highways with backlog deficiencies and some

Exhibit 4-7
Maintain 1989 Conditions and Performance
2.5% VMT Growth Rate
(billions of 1989 dollars)

Improvement Type	Capacity	Pavement	Total
Rural			
Interstate	35.6	23.9	59.5
Other Principal Arterial	26.4	22.9	49.4
Minor Arterial	24.1	34.7	58.8
Major Collector	28.6	64.1	92.7
Minor Collector	11.4	26.5	38.0
Subtotal	126.2	172.1	298.3
Urban			
Interstate	52.6	27.6	80.2
Other Freeway & Expressway	28.6	14.9	43.5
Other Principal Arterial	58.5	36.8	95.4
Minor Arterial	43.2	40.6	83.8
Collector	25.6	35.5	61.1
Subtotal	208.6	155.4	363.9
Total	334.8	327.5	662.2
Annual	16.7	16.4	33.1

highways with accruing deficiencies, depending on the relative cost-effectiveness of different improvements. Whatever accruing deficiencies were not met in any given year under this scenario would become backlog in the future, thereby changing the nature of the backlog.

The *Maintain Overall 1989 Conditions and Performance* scenario would result in a shortfall of about 22,000 lane-miles of capacity in larger urbanized areas, using the capacity restraints discussed under the *Improve Condition and Performance* scenario. Under this scenario, performance in some larger urbanized areas could not be maintained, even with a vigorous capital improvement program and operational strategy. Exhibit 4-8 shows current and future lane-miles for this investment strategy.

Exhibit 4-8
Total Lane-Mile Requirements
Cost to Maintain 1989 Conditions and Performance

		2009 Lane-Mile Required		
Functional System	1989	Expansion Capacity	New ROW/Higher Cost Capacity	Total
Rural				
Interstate	134,969	179,809	4,062	183,871
Other Principal Arterial – High	74,095	135,021	4,209	139,230
Other Principal Arterial – Low	131,723	87,309	71	87,380
Minor Arterial	308,266	323,339	5,891	329,230
Major Collector	880,650	892,222	4,835	897,057
Minor Collector	586,998	588,767	274	589,041
Subtotal	2,116,701	2,206,467	19,342	2,225,809
Urban				
Interstate	61,854	77,415	8,889	86,304
Other Freeway & Expressway	33,739	42,226	3,600	45,826
Other Principal Arterial	170,977	190,020	19,175	209,195
Minor Arterial	188,218	211,133	18,076	229,209
Collector	167,699	182,982	12,388	195,370
Subtotal	622,487	703,776	62,128	765,904
Total	2,739,188	2,910,243	81,470	2,991,713

Note: Maximum number of lanes = 12. High principal arterials carry greater than 6,000 vehicles per day. Low principal arterials carry less than or equal to 6,000 vehicles per day.

Investment Scenario Comparisons

The distribution of investment by highway system would be significantly different under the *Maintain Conditions and Performance* scenario than under the *Improve Condition and Performance* scenario because of the differences in the conditions of roads at the beginning of the analysis period. The principal arterials are in much better condition, on average, than the collector systems. For this reason, the cost to *Maintain Condition and Performance* on the principal arterials is relatively high compared to requirements on the collectors. Also, future travel demand on the principal arterials is expected to exceed demand on the collectors and minor arterials.

The total *Maintain Condition and Performance* scenario cost is approximately 57 percent of the *Improve Condition and Performance* investment requirement. Under the *Maintain Condition and Performance* scenario, about 55 percent of total investment would occur in urban areas, compared to 68 percent under the *Improve Condition and Performance* strategy. Capacity improvements would account for about 57 percent of urban investment, and 51 percent of total investment. These values are similarly lower than their respective *Improve Condition and Performance* counterparts.

100,000 miles of highway require pavement work each year to restore serviceability.

The cost to maintain rural conditions is about 78 percent of the *Improve Condition and Performance* requirements for rural highways, while in urban areas, the value is slightly less than 50 percent. Among functional systems, the cost to maintain rural Interstate System conditions and performance is about 95 percent of the *Improve Condition and Performance* requirement, indicative of the current high levels of condition and performance on that system. The cost to maintain urban arterials, on the other extreme, is about 50 percent of *Improve Condition and Performance* requirements on those systems. This disparity reflects the differential rate of travel growth between urban and rural areas expected through 2009.

The most significant difference between *Improving* and *Maintaining* 1989 Conditions and Performance is the extent of highway capacity that is simulated, particularly in urbanized areas. Exhibit 4-9 illustrates the impacts of the procedural changes discussed above and the congestion management program simulated in addressing urban capacity requirements. The exhibit shows, for the *Maintain Conditions* scenario for all urban areas, existing lane-miles of capacity compared with lane-miles resulting from each of the changes. Exhibits 4-10 and 4-11 show similar results for (1) all urban areas, (2) all urbanized areas, and (3) the top 10 urbanized areas for both the *Improve Conditions* and the *Maintain Conditions* scenarios.

Other Highway Investment Requirements

In addition to the pavement, capacity, and structural components of total highway and bridge infrastructure requirements, included within the HPMS and BNIP systems there are additional investment requirements which have not been included in prior congressional reports. These have been added to provide improved comparability between report scenarios and actual investment. The following sections include a discussion of these areas and cost estimates to meet the requirements summarized in each.

Highway Network Requirements to Accommodate Suburban Growth

The procedures used in this report calculate future urban highway requirements based on current urban boundaries. However, as urban areas grow, rural land adjacent to urban areas takes on the land use and travel character of urban fringe and fringe areas take on the character of suburban areas.

The HPMS Analytical Process calculates all deficiencies and investment requirements for roads within the area that is currently considered rural as rural design standard lane mile additions, even if they would become urban in the future. To incorporate the basic infrastructure requirements in expanding suburban areas, a procedure was developed to simulate the expected growth in urban areas and to calculate new lane-miles of roadway that will be required to accommodate the growth at minimum conditions standards. The procedure uses historic data of the functional system mileage distribution by individual urban area. A disaggregated travel forecast for each urban area that provided the number of lane-miles of facility that will be required to maintain a specified level of service was prepared.

Exhibit 4-12 summarizes the lane-mile requirements resulting from this procedure. Urban or rural estimates have been adjusted to eliminate overlap. Unit costs for these improvements represent new rural highway construction

Exhibit 4-9
Urban Capacity

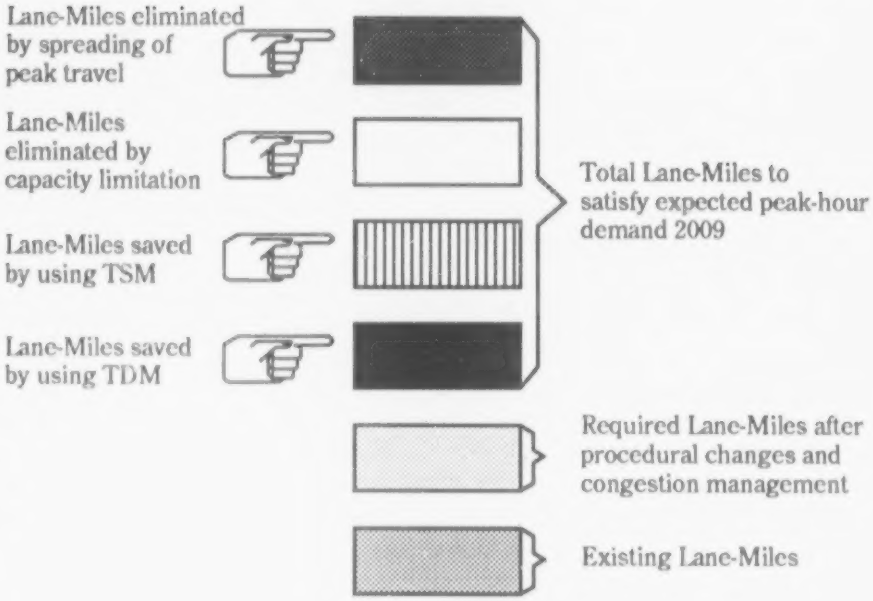
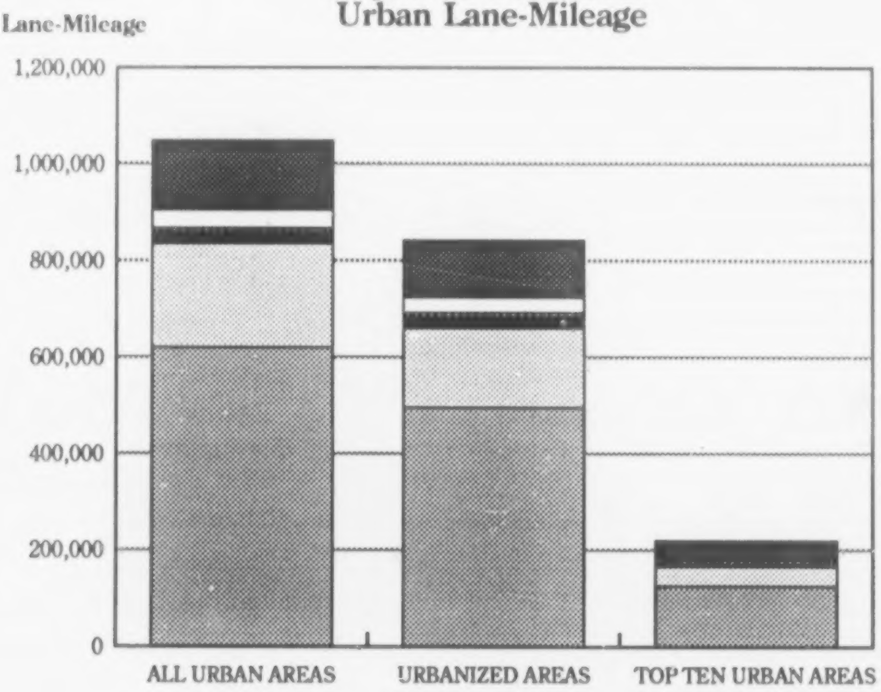
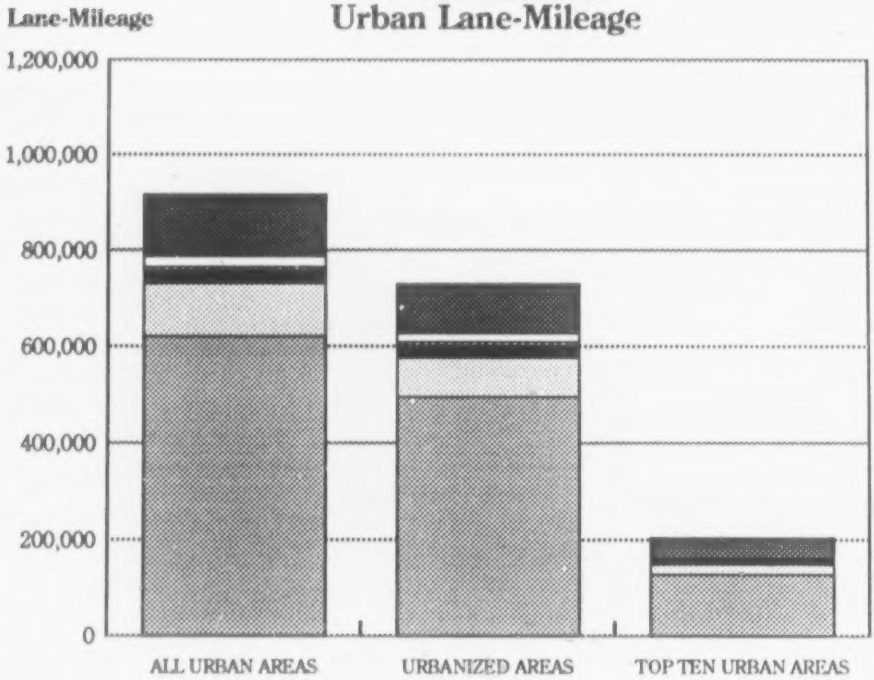

Lane-Miles eliminated by spreading of peak travel
Lane-Miles eliminated by capacity limitation
Lane-Miles saved by using TSM
Lane-Miles saved by using TDM
Total Lane-Miles to satisfy expected peak-hour demand 2009
Required Lane-Miles after procedural changes and congestion management
Existing Lane-Miles

Exhibit 4-10
Improved Conditions
Urban Lane-Mileage



See Exhibit 4-9 for key

Exhibit 4-11
Cost to Maintain Urban Lane-Mileage



See Exhibit 4-9 for key

Exhibit 4-12
Suburban Highway System Requirements
1990 - 2009

Functional System	New Lane-Miles	Cost ($ billions)
Freeways	12,100	18.8 – 37.7
Other Principal Arterials	15,200	17.5 – 35.4
Minor Arterials	16,400	15.2 – 30.5
Collectors	8,100	8.8 – 17.7
Local Roads	300,000	60.0 – 90.0
Total (Average Annual)	351,800 (17,590)	120.3 – 211.3 (6.0 – 10.5)

and reconstruction costs for facilities on the fringes of existing urban areas as reported in actual Federal-aid project records.

Local Road Capital Requirements

The HPMS data system does not cover conditions or capital investment requirements for the approximately 2.6 million miles of roads functionally classified as local roads. The estimates included were derived from surrogate information obtained from county engineers and highway officials in 1987 for the U.S. Department of Agriculture (USDA)[1].

By FHWA standards, between 35 and 50 percent of all local rural roads are currently in "poor" condition, implying either significantly higher levels of continuing maintenance or capital improvement to restore serviceability or significant deterioration with normal travel demand and weathering. Assuming that local urban roads exhibit similar conditions and unit costs and using USDA unit costs per mile of $9,300 (1989) to upgrade local rural roads to minimum conditions standards, the estimate for improving all local roads that are at or near failure would be between $8.5 and $12 billion through 2009, or between $425 and $600 million annually in 1989 dollars.

An annual investment of this magnitude would restore serviceability to between 900,000 and 1.3 million miles of local roads that are currently, or will become deficient through 2009. The lower estimate is shown in the summary exhibit below as the local road investment associated with the Maintain Conditions and Performance scenario, and the higher estimate is associated with the Improve Conditions and Performance scenario.

Defense Highway Requirements

The Nation's highway and bridge systems are an integral part of the national defense transportation system. The military relies on the highway system for peacetime transit of military shipments, as well as for wartime or emergency mobilization and deployment of military units. The STRAHNET, consisting of the Interstate System and about 16,800 miles of other principal arterials, is the primary network of defense concern.

An estimated $600 million, or $30 million annually will be required to meet defense specific costs on STRAHNET which include the cost of 12 foot lane-widths where not otherwise required. These are in addition to any estimates shown elsewhere. Not included are costs for the Defense Connector Systems unless those costs are coincident with other HPMS generated estimates.

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[1] Rural Roads and Bridge: Where Do We Go From Here? U.S. Department of Agriculture, Office of Transportation, 1990.

Bridge Investment Requirements, 1990-2009

Changes to the Bridge Investment Estimation Procedures

In 1989, a new procedure was developed for estimating bridge investment requirements. This procedure, the Bridge Needs and Investment Process (BNIP), is able to calculate both backlog and accruing deficiencies and investment alternatives for all bridges. Instead of a sufficiency rating system, the BNIP uses minimum condition standards to determine deficiencies and simulate investment strategies and a "look ahead approach" similar to the highway analytical procedure.

The 1989 report noted that the bridge estimates were preliminary and subject to revision, as users tested and evaluated the assumptions and logic used in the BNIP. Based on these evaluations, the BNIP has been changed and several new procedures added. The separation of highway pavement, structure and functional-related deficiencies from bridge structural or geometric deficiencies has eliminated the need to adjust for double counting. The minimum bridge condition standards have been upgraded to simulate the load requirements of emergency and public use vehicles and the load rating procedures have been refined to reflect actual span lengths.

Exhibit 4-13 summarizes bridge conditions, as of June 30, 1990.

Backlog Bridge Requirements

As of June 30, 1990, backlog requirements alone on the Nation's inventory of arterial, collector, and local road bridges were $91 billion. The cost of retiring the backlog of bridge deficiencies could increase to as much as $131 billion, depending on the number of years required to meet that objective, because of the deferred capital cost of bridge repair.

If bridge structural and deck deficiencies are not identified and repaired in timely fashion, further deterioration could result in major rehabilitation or bridge replacement requirements, which cost significantly more than highway repair, on a unit cost basis. In addition, deferred investment on deficient bridges

Exhibit 4-13
Bridge Deficiencies, 1990

Functional System	Structurally Deficient	Functionally Obsolete	Total Deficiencies	Total Bridge on the System
Interstate	3,848	11,360	15,208	53,183
Other Arterial	15,989	23,502	39,491	124,615
Collector	33,056	23,566	56,622	164,300
Local	81,179	33,326	114,505	234,567
Total	134,072	91,754	225,826	576,665

7,000 arterial and collector bridges require rehabilitation or replacement each year.

may impose a public safety hazard that exceeds the risk imposed by a deferred highway improvement.

The Improve Bridge Conditions Scenario

The average annual investment required to repair all backlog and accruing bridge deficiencies on all arterial, collector, and local road bridges over the period 1990-2009 is between $6 and $8.5 billion, depending on the number of years taken to repair backlog deficiencies.

At these investment levels, all backlog bridge deficiencies would be retired through bridge replacement, rehabilitation, or major widening, and all accruing requirements would be met through 2009. Bridge investment requirements are relatively insensitive to future travel growth.

Between 50 and 75 percent of the cost of bridge repair and replacement is as a result of structural deficiencies. The remainder is a result of functional obsolescence.

Maintain Current Bridge Conditions Scenario

The average annual cost to maintain overall bridge conditions as they were reported on December 31, 1989 is estimated at $4.2 billion annually through 2009. This investment level would maintain the current total number and distribution of structurally deficient and functionally obsolete bridges.

Exhibit 4-14 summarizes 1990-2009 investment requirements to eliminate all backlog and accruing bridge deficiencies for all bridges greater than 20 feet in

Exhibit 4-14
Cost to Improve Bridge Conditions
1990 – 2009

Functional System	Number of Repaired or Replaced Bridges	1990–2009 Requirements (billions)	Annualized Requirements (billions)
Rural			
Interstate	11,871	11.1	0.56
Other Principal Arterial	10,828	7.2	0.36
Minor Arterial	11,924	7.1	0.36
Major Collector	56,639	8.0	0.40
Minor Collector	25,940	3.5	0.18
Subtotal Non-Local	117,202	36.9	1.85
Local	127,291	12.0	0.60
Total	244,493	48.9	2.45
Urban			
Interstate	20,156	32.1	1.61
Other Freeway & Expressway	5,682	9.0	0.45
Other Principal Arterial	11,302	15.6	0.78
Minor Arterial	8,370	8.2	0.41
Collector	6,786	3.0	0.15
Subtotal Non-Local	52,297	67.9	3.40
Local	8,480	3.5	0.17
Total	60,777	71.4	3.57
Total Non-Local	169,499	104.8	5.24
Total	305,270	120.3	6.02

length, including those on local roads. All box culverts are also included, regardless of length. Exhibit 4-15 summarizes the cost to maintain overall bridge conditions as they were reported on December 31, 1989. Between 55 and 75 percent represents costs attributable to structural deficiencies.

Total Investment Requirements

Exhibit 4-16 summarizes all investment requirements discussed in this chapter. Costs derived from new HPMS estimates are presented for each functional system — urban and rural. These investment requirements are supplemented by the other highway requirements, providing a more complete estimate of total national conditions and performance-related investments for improved comparability with actual national investment levels. The impacts of a fully implemented traffic management strategy are included within each appropriate functional system category. The remaining cost-to-complete the Interstate System, estimated at $6.3 billion in January, 1991, is ***not included*** in Exhibit 4-16.

Technical Background

The Highway Investment Analysis Procedure

Any specific statement of highway and bridge requirements is framed around a given set of assumptions about future travel growth, minimum condition and design standards, and system extent. Similarly, an array of investment possibilities exists, depending on the availability of funds, the public's demand for additional highway capacity, and the social and environmental costs of various investment decisions.

Future system conditions and performance are a function of current conditions, future travel demand, and capital and maintenance commitments to highway and bridge infrastructure. Adequate future highway service will be determined by how closely capital requirements and capital commitments track. Past investment has not kept pace with system demands. It is for this reason that system performance has declined.

Highway Travel Forecasts, 1990-2009

The first step in assessing future highway investment requirements is to simulate the effect of future years' travel on the existing highway network. The HPMS database and analytical process are used for this analysis.

The HPMS database contains approximately 100,000 sample highway sections, statistically sampled by the States to represent traffic volume groups by functional system within the rural and urban portions of each State. Data for these samples relating to highway physical conditions, safety, and operating characteristics are compiled by the States and submitted to FHWA annually, along with information regarding any capital investments made on the segment.

This database, accumulated to provide a time-series view of highway conditions and performance, is used to assess conditions, calculate future deficiencies, and to

Exhibit 4-15
Cost to Maintain Bridge Conditions
1990 – 2009

Functional System	Number of Repaired or Replaced Bridges	1990–2009 Requirements (billions)	Annualized Requirements (billions)
Rural			
Interstate	8,293	7.8	0.39
Other Principal Arterial	6,099	4.1	0.20
Minor Arterial	2,131	1.3	0.06
Major Collector	7,570	1.1	0.05
Minor Collector	19,598	2.6	0.13
Subtotal Non-Local	43,691	16.9	0.84
Local	76,188	7.2	0.36
Total	119,879	24.0	1.20
Urban			
Interstate	19,983	31.8	1.59
Other Freeway & Expressway	5,540	8.8	0.44
Other Principal Arterial	8,977	12.4	0.62
Minor Arterial	3,820	3.7	0.19
Collector	1,629	0.7	0.04
Subtotal Non-Local	39,949	57.5	2.87
Local	6,195	2.5	0.13
Total	46,144	60.0	3.00
Total Non-Local	83,639	74.3	3.71
Total	166,022	84.0	4.2

Exhibit 4-16
Summary of All Annual Highway and Bridge Investment Requirements, 1990 – 2009 (billions of 1989 dollars)

Functional Systems	Cost to Maintain 1989 Conditions and Performance	Cost to Improve 1989 Conditions and Performance
Rural		
Interstate	3.0	3.3
Other Principal Arterial	2.5	3.7
Minor Arterial	2.9	3.7
Major Collector	4.6	5.4
Minor Collector	1.9	3.0
Local Roads	0.2	0.2
Subtotal	15.1	19.3
Urban		
Interstate	5.0	11.7
Other Freeway & Expressway	2.6	4.7
Other Principal Arterial	6.0	13.1
Minor Arterial	5.3	10.3
Collector	3.7	6.0
Local Roads	3.8	3.8
Subtotal	26.4	49.6
Urban and Rural Subtotal	41.5	68.9
Bridge	4.2	6.0
Total Annual Highway and Bridge Requirements	45.7	74.9

estimate capital investment requirements. The HPMS database and analytical procedures are constantly under review to refine, enhance, and verify individual data items and simulation results. This effort produces a flexible tool for developing and evaluating alternative policies and programs; for testing future budget and program scenarios; and for describing the social and economic impacts of changes in highway conditions and performance.

In the HPMS data system, the States forecast travel growth on each of the highway sections that make up the national sample. Since current actual travel is known, and future travel is forecast, the average annual travel growth rate can be calculated by summing the State estimates and calculating the compound rate.

The national rate calculated by summarizing State estimates from the 1989 HPMS data submittal suggests that highway travel will increase at an average annual rate of over 2.5-percent through 2009. The 2.5-percent national average is higher than the 2.3-percent 1987-2005 forecast used in the last report, but well below the rate of travel growth actually experienced from 1987 through 1989. The growth rate from 1987 to 1988 was 5.45-percent and the rate from 1988 to 1989 was 4.0-percent. Based on preliminary 1990 estimates, the 3-year average from 1987 through 1990 will be about 4.0-percent per year.

The variation of travel growth forecasts among States is substantial, from 0.49 percent to 5.3-percent per year. The distribution of travel growth by State is very similar to the 1987 database, with 14 of the highest 20 States from 1987 also among the highest 20 in 1989.

Travel growth is expected to vary significantly by density of development. Exhibit 4-17 shows expected growth for rural, urban, urbanized, and top 10 urbanized areas.

An annual average growth rate of 2.5-percent suggests that travel growth from 2000-2009 will be well below historic levels. To reflect future travel conditions more in line with historic levels, the State estimates were individually adjusted to reflect an overall national growth rate of 3.0-percent through 2009.

A 3.0-percent average annual travel growth rate implies a more gradual reduction in the rate of increase, compared to that implied by the 2.5-percent rate. Assuming a linear reduction in the rate of travel growth, a 3.0-percent average annual growth rate suggests that the expected growth rate in 2009 would be about 2.1-percent. The 2.5-percent average annual growth rate suggests that the growth rate in 2009 would be about 1.1-percent. Both of these statements assume that future rates of growth in travel will decline *gradually* from current growth rates. If current rates of growth remain stable for several years *before* the expected reductions take effect, the impact on future growth would be more dramatic.

Exhibit 4-17
Forecasted and Simulated Travel Growth Rates

	Forecast * Travel Growth Rates 1990-2009	**Simulated** * Travel Growth Rates 1990-2009
Rural Areas	2.58%	2.58%
Small Urban Areas	2.49%	2.49%
All Urbanized Areas	2.45%	1.42% – 1.46%
Top 10 Urbanized Areas	1.99%	1.21%
Total	2.51%	

* The forecast growth rates are those coded in the 1989 HPMS database. The simulated rate for which capacity costs are determined assume peak spreading and a 12-lane restriction on facilities in urbanized areas.

By way of comparison, both the 2.5 and the 3.0-percent growth rates are lower than recent years' experiences in highway travel. For the period 1966-1988, the rate of growth in highway travel averaged 3.5-percent annually. Except for the periods 1973-1974 and 1979-1982, the years of the radical fuel price adjustments attributable to the OPEC cartel and the recession of the early 1980's, travel growth has exceeded 3.0-percent in each year since 1966.

Once future travel forecasts are made, system deterioration is simulated by estimating the combined effects of future travel on and aging of a highway's physical and operating characteristics. The degree and rate of physical deterioration, which varies by functional system, is measured primarily as changes in pavement condition. The key determinants of physical condition and rate of deterioration are:

- pavement type and thickness;
- drainage adequacy;
- traffic volume and mix of vehicle types; and
- the remaining design life of the highway.

The rate of highway performance deterioration is measured primarily in changes to the volume/service flow, or volume compared to available capacity. The key determinants of performance deterioration are:

- the number and widths of available lanes;
- traffic volume and mix of vehicle types;
- the number and severity of curves and grades; and
- the number and severity of speed change cycles.

Minimum Conditions Standards. The deterioration simulation is carried out in yearly intervals. For each interval, the physical and operating conditions are compared against a prescribed set of minimum condition standards. Exhibits 4-18 and 4-19 contain the minimum condition standards for each functional system used in this report. The minimum condition standards used here are the same as those used in both the 1987 and 1989 reports to Congress.

The selection of minimum condition standards is based on a consensual approach among highway engineering professionals at the Federal and State levels. The standards selected for physical highway conditions are designed to minimize life cycle capital and maintenance costs while ensuring the safety of the motoring public. The standards for highway performance are set to ensure a minimum level of performance equivalent to level of service E. This is the point at which traffic flow becomes highly unstable, with stop and go conditions that

Exhibit 4-18
Rural Minimum Conditions Standards (MCS)

	Interstate			Other Principal Arterials						Minor Arterials						Major and Minor Collectors								
	All ADT			Greater than 6000			Less than or equal to 6000			Greater than 2000			Less than or equal to 2000			Greater than 1000			400 – 1000			Less than 400		
Terrain	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M	F	R	M
Lane Width (ft.)	12	12	12	11	11	11	11	11	11	10	10	10	10	10	10	10	10	10	8	8	8	16	16	16
Rshld Width (ft.)	8	8	6	8	8	6	8	8	6	6	6	4	6	6	4	4	4	4	2	2	2	0	0	0
Shld Type	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
Pave Cond	3.0	3.0	3.0	3.0	3.0	3.0	2.8	2.8	2.8	2.4	2.4	2.4	2.4	2.4	2.4	2.0	2.0	2.0	2.0	2.0	2.0	1.8	1.8	1.8
Oper Speed (mph)	50	45	40	50	45	35	45	40	35	40	35	30	30	30	25	30	25	20	0	0	0	0	0	0
V/C Ratio	0.75	0.75	0.75	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
Surf Type	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	4	4	4	5	5	5
Hor Align	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3
Ver Align	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3

Note: Terrain Types are Flat, Rolling and Mountainous.
MTC Shown for Lane Width on Collectors Group 4 are for Surface Width.
V/C Ratio MCS are used only for sections in densely developed areas where operating speed is not applicable.

HPMS Shoulder Type Codes:
1 — Surfaced
2 — Stabilized
3 — Earth
4 — Curbed

HPMS Surface Type Codes:
1 — High Flexible
2 — High Rigid
3 — Intermediate
4 — Low
5 — Gravel

HPMS Horizontal/Vertical Alignment Codes:
1 — All Curves/Grades Meet Design Standards
2 — Some Curves/Grades Below Design Standards
3 — Curves/Grades with Reduced Speed
4 — Several Curves Unsafe/Significant Reduction of Speed on Grades

Exhibit 4-19
Urban Minimum Conditions Standards (MCS)

		Interstate	Other Freeways & Expressways	Other Principal Arterials	Minor Arterials	Collectors
Operating Speeds	Built-up	30	30	—	—	—
	Outlying	35	30	—	—	—
Volume-to-Capacity Ratio		0.90	0.90	0.90	0.95	0.95
Lane Width (ft.)		12	11	10	8	8
Surface Type		2	2	2	3	4
Pavement Condition		3.2	3.0	2.8	2.4	2.0
Shoulder Type		1	1	2	3	3
Right Shoulder Width (ft.)		8	8	6	6	6

HPMS Shoulder Type Codes:
1 — Surfaced
2 — Stabilized
3 — Earth
4 — Curbed

HPMS Surface Type Codes:
1 — High Flexible
2 — High Rigid
3 — Intermediate
4 — Low
5 — Gravel

increase delay, increase fuel consumption, vehicle emissions, and highway user costs.

Deficiency and Investment Analysis Procedures. As each highway section is analyzed, the simulated physical and operating characteristics are compared yearly against the minimum condition standards. If one or more standards is not met during the simulated year's worth of highway use and deterioration, the process notes a deficiency and identifies a suitable capital improvement to remove the deficiency. The type of improvement simulated depends on the particular deficiency or combination of deficiencies noted, and the stage in the highway section's usable design life during which the deficiency occurs.

Improvements are broadly categorized as those occasioned by a condition deficiency and those occasioned by a performance deficiency. Condition requirements refer to minimum acceptable pavement condition, surface type, shoulder width, or some other geometric or cross-sectional consideration designed to prolong the usable life of the road or to enhance the safety of motorists. Physical requirements result in either resurfacing or reconstruction improvements, possibly with shoulder or alignment improvements to eliminate unsafe curves and grades. The specific improvement type depends on the severity and nature of the deficiency.

Performance requirements refer to minimum conditions for operating performance, usually expressed as volume/capacity during the peak-hour. Performance requirements result in the addition of capacity to the existing roadway, either by converting the road to a freeway type of design, or by adding lanes. Whenever capacity is added in the HPMS simulation procedure, the entire road is resurfaced. This procedure is in keeping with actual State practices.

The disaggregation into condition and performance driven improvement is purely informational. It does not indicate priority or cost-effectiveness.

At this point, the analysis has identified a deficiency and has specified an appropriate improvement to be made to repair the deficiency. Each improvement has a cost per lane-mile based on national cost estimates that have been modified to reflect variations in average State project costs. All dollar estimates are in 1989 dollars.

The investment analysis then determines whether sufficient funds are available to effect the needed improvement. If unlimited funds are available, all deficiencies are repaired. If funds are limited, the investment analysis selects improvements based on the cost-effectiveness of one improvement compared to another.

In this manner, the procedure prioritizes improvements based on the amount of funds available and the relative improvement in system condition and performance that can be realized by different combinations of improvements. The determination of cost-effectiveness is flexible. Cost-effectiveness can be measured as a change in the miles of improved conditions or the change in the amount of travel benefitted by the improved condition. For this analysis, cost-effectiveness has been weighted by mileage.

When a deficiency is identified and the selected improvement has been simulated, condition and performance indicators for that highway are upgraded to reflect the improved condition. The improved condition depends on the type of improvement selected, and the condition of the highway when the improvement is simulated. A segment may have more than one improvement simulated over a 15 to 20-year analysis period.

Congestion Management Strategies to Address Highway and Bridge Investment Requirements

In addition to construction of new capacity, this report incorporates the effects of low capital intensive highway-related congestion management strategies including both traffic operations and demand management strategies, designed to improve the efficiency of the highway and bridge network, especially in urban areas.

Congestion management strategies for highways may be broadly classified as demand or supply oriented. Such strategies may include, among other options, incident management programs, ramp metering, coordinated signalization, and other traffic engineering improvements. In the future, the possibilities associated with intelligent vehicle highway systems (IVHS) will increase the potentials of these programs.

Travel demand management (TDM) programs include, among other options, enhanced ridesharing and transit programs, parking management, tolls, congestion pricing, and flextime. The effects of any of these TDM strategies are to:

- use available highway capacity more effectively;
- eliminate impediments to smooth traffic flow;
- reduce peak-hour demand for capacity; and/or
- reduce overall travel demand.

The effect of such congestion management actions can be translated into ***new lane-miles of capacity not required***, thus into reduced investment requirements.

The selection of appropriate traffic management strategies depends on the urban development pattern, travel patterns, existing transportation facilities and service levels, local predisposition, and other factors. For example, an area with large employment centers may find a coordinated program of TDM, such as ridesharing, flextime, transit and parking incentives, combined with high occupancy vehicle (HOV) lanes, to be a particularly effective and publicly acceptable mix of demand management and supply enhancement strategies to address peak-period congestion. Another area with less site-specific congestion problems may opt for broader based supply oriented strategies, such as incident management, ramp metering, and systemwide coordinated signalization, transit, and HOV improvements, or land-use based parking and facility pricing approaches.

All of these efforts would supplement a highway capital program that included appropriate capacity improvements to provide a "manageable infrastructure" which could support the selected operations strategies, transit enhancements or demand-based tactics.

Development of a Prototypical Coordinated Strategy. Although it is not possible to design a coordinated management program to fit the setting and requirements of all urban areas equally, a prototypical strategy with widely applicable and mutually reinforcing elements was developed and incorporated into the investment requirements analysis for the purposes of demonstrating the possible savings that could be achieved.

It should be emphasized that the presumption of consistent across the board application of these programs in all urban areas represents an aggressive approach given the poor record of urban areas in systematic applications to date.

Freeway surveillance and control, HOV facilities, ramp metering, incident management, signalization improvements, traffic channelization, and minor widening (restriping the existing pavement) are the major features chosen to represent capacity enhancement. The application of this strategy has the potential of increasing the effective capacity of highways — existing or new —by between 30 and 65 percent on a subset of limited access facilities where their application appears to be cost-effective. On non-access controlled facilities, the strategy simulated includes a mix of traffic engineering improvements, including signal coordination, signal removal, and traffic operations improvements. The application of these strategies is expected to provide an additional 25-percent capacity increase on a corresponding subset of non-access controlled arterials.

For purposes of the investment analysis in this report, the capacity increase of these operations improvements is simulated as an equivalent reduction in future travel demand.

On the demand side, a coordinated program was simulated assuming coordinated ridesharing, parking incentives, transit enhancement and high-occupancy vehicle incentive programs. The effect of this program was assumed to shift one out of every ten drivers of single occupant vehicles during the peak-period to some form of ridesharing or mass transit. This level of success could be expected for high occupancy vehicles along major corridors. In an area with an existing average vehicle occupancy of 1.1, implementation of this strategy could be expected to raise the average peak-period vehicle occupancy to about 1.23. This implies a significantly higher number of persons per vehicle for work trips. Under an assumption that work trips constitute, on average, 40 percent of afternoon peak-period travel, 1.23 persons per vehicle implies a vehicle occupancy rate of 1.6 for commuter vehicles. In 1985, the most recent year for accurate data, work trip vehicle occupancy in larger urbanized areas was estimated at 1.15.

To date, the ability to effect this magnitude of vehicle occupancy shift has been demonstrated in only a few freeway corridors, and usually associated with fuel unavailability, severe traffic congestion, or air quality initiatives.

Simulation of the Combined Congestion Management Strategies. The combined effects of the operations and demand-oriented strategies are to reduce travel demand by between 3 and 8 percent through 2009. Travel demand reductions of these magnitudes could reduce the future capacity required by as many as 34,000 lane-miles.

The applications of the operations-oriented supply enhancements, alone, reduces the investment requirements by as much as $1.2 billion per year, assuming a 3.0-percent travel growth rate. The application of combined strategy reduces the estimate by as much as $3.4 billion per year. Such impacts assume that the coordinated strategy outlined above, or some other combination of actions yielding the same results in demand reduction or supply enhancement, would be fully implemented by *all* metropolitan areas with capacity problems where such improvements were considered cost-effective.

The Cost of Deferred Capital Investment

Historically, total actual investment has always been less than that required to maintain the overall serviceability of roads. The average condition of roads has deteriorated, as has the average operating performance. Consequently, the backlog of needed improvements has increased, and the nature of future improvements to remedy expected problems has changed. The cost of deferral added $8 to $12 billion to the cost of remedying backlog deficiencies between 1987 and 1989. Future deferred costs could be as high as $8 billion annually, depending on the timeliness of addressing backlog deficiencies.

The total cost of deferral has three components:

- the capital cost associated with a more expensive type of improvement to repair a more significant problem;
- the increased user cost incurred during the improvement, consisting of detouring, delay, and higher numbers of accidents through and around construction zones; and
- the highway vehicle operating costs and lower speeds imposed on highway users over the time between identification of the problem and the time of improvement.

Deferring any highway improvement, beyond the point at which its condition and/or performance warrants the improvement, increases the cost that must ultimately be paid by highway users to restore the road's serviceability. Between the time that a need for improvement is identified and action is taken, the roadway continues to deteriorate.

If the problem identified happens to be a physical problem, for example, cracking and rutting of the pavement, delaying an improvement can expose the pavement to continued deterioration. If remedial action is taken in timely fashion, a simple resurfacing may be all that is required to restore the road's serviceability. If, on the other hand, action is delayed, further deterioration can allow the surface pavement stress to extend into the road's base and subbase. Pavement damage from freeze/thaw action on slightly damaged pavement is a classic example. When this happens, a more costly pavement reconstruction improvement will be required, at a cost almost 3 times as high as the cost for resurfacing. Not only will the cost be higher, but the time and public inconvenience of major reconstruction far exceeds that required for simply resurfacing.

The same type of cost deferral is true of performance related deficiencies, as well. The only difference is that a higher share of the total deferred cost is represented by the increased delay and congestion imposed on highway users.

The deficiency, investment requirements, and investment/performance analyses used here, and the similar procedures developed to assess bridge requirements, view the highway and bridge infrastructure as capital assets rather than as consumer goods. Both procedures use long-term, rather than short-term approaches to estimating needs. The procedure "looks ahead" when a deficiency is identified and an improvement type is selected. This allows the procedure to consider service requirements several years into the future.

For example, the procedure may identify a pavement deficiency that requires a resurfacing improvement. If it "looks ahead," however, and finds that in a few years the travel demand will call for added lanes, the procedure will waive the resurfacing and wait until the capacity improvement is needed. At that time, the procedure will simulate the cost of resurfacing the road at the same time the capacity is improved. This procedure emulates actual State practice in programming projects. Because the investments are made to address existing problems, as well as impending problems, the highway system always has a residual service value.

If capital estimates were made solely to satisfy current system requirements, without regard for future requirements, the result would be the constant depreciation of the system's residual value. Such an investment strategy could minimize annual capital requirements. Over a sustained period of such a strategy, however, the residual value of the system would be seriously depreciated. Although the short-term capital costs would be lower, the long-term cost of deferral would be substantially higher.

Glossary

Accruing deficiency

A highway or bridge condition that will violate the minimum condition standards in a future year. Accruing deficiencies are a function of normal pavement and bridge deterioration, travel demand, age, capital investment, and the adequacy of maintenance.

Ad valorem tax

A tax based on the value of a commodity. Taxes are either ad valorem or specific; a tax is ad valorem when the duty is laid in the form of a percentage on the value of the property; a tax is specific when it is imposed as a fixed sum on each article of a class without regard to its value, e.g., a gallonage tax.

Annual average daily traffic (AADT)

Average daily traffic, averaged over a full year.

Backlog deficiency

A highway or bridge condition that violated one or more minimum condition standards at the beginning of the analysis period; in this report, 1989 for highways and 1990 for bridges.

Bridge, functionally deficient

A bridge on which the deck width or vertical clearance cannot accommodate the traffic volume or size of vehicles that need to use the bridge, or the waterway under the bridge cannot accommodate the required volume of water.

Bridge, structurally deficient

A bridge that cannot carry the required truck loads.

Capacity

The theoretical maximum number of vehicles that has a reasonable expectation of passing over a given section of a lane or a roadway in one direction (or in both directions for a two-lane or three-lane highway) during a given time period under prevailing roadway and traffic conditions.

Capital costs

Expenditures associated with highway improvements including right-of-way and related expenses, preliminary and construction engineering, and construction. (Also see definition for non-capital costs.)

Cost to improve overall conditions

The average annual total capital cost, usually expressed in constant dollars, of eliminating the backlog of highway and bridge deficiencies over the analysis period, as well as meeting accruing requirements.

Cost to maintain overall conditions

The average annual total capital cost, usually expressed in constant dollars, of keeping the highway or bridge system as good or bad, overall, as it was in the base year, 1989 for highways, 1990 for bridges. Some facilities will be better and some worse than today but, overall, the condition and performance will remain approximately the same. Due to a lack of right-of-way, performance in the largest urbanized areas cannot be maintained at the investment levels, since there is insufficient capacity to satisfy existing and expected travel demand.

Deficiency

A highway condition or performance element that is below a specified acceptable level. These minimum levels represent a consensus of technical expertise within the highway engineering discipline.

Federal-aid program

A cooperative effort between the Federal and State governments that provides funding for identified highway projects. The designated highway systems in the program include the Federal-aid Interstate System (FAI), the primary system (FAP), the secondary system (FAS), and the urban system (FAU).

Highway-user imposts

Includes taxes, fees, charges and tolls levied on motor vehicles and their usage. These include motor fuel taxes (gasoline, special fuel, diesel), motor vehicle registration fees, operator's licenses, motor carrier fees (ton-mile) or any charge specifically targeted to road-users. These fees do not include broad-based taxes such as sales, property, or income taxes.

Indexing

A tax method that links tax rates to independent variables, such the price of motor-fuel or highway cost.

Lane-mile

A measure of highway distance that takes into account the number of lanes. The amount of lane-miles for a given highway section is equal to the length of the section (in miles) multiplied by its number of lanes.

Level of service (LOS)

Qualitative description of operational conditions within a traffic stream. The six levels of service are briefly described below.

A – Free flow, with drivers unaffected by other vehicles in the traffic stream.

B – Stable flow, but there is enough traffic to slightly effect the freedom to maneuver.

C – Stable flow, but traffic operation is significantly affected. Both speed and freedom to maneuver are affected.

D – High-density stable flow. Speed and freedom to maneuver are severely restricted. Small increases in traffic flow cause operational problems.

E – Operations at or near the capacity of the facility. Speeds are reduced to a low value. Freedom to maneuver is extremely limited. Operation is usually unstable, because small disturbances in the traffic stream will cause breakdowns in the flow.

F – Breakdown flow. Occurs when the amount of traffic exceeds the volume which can traverse a given point. Traffic is stop and go.

Minimum condition standards

A series of physical and operating system performance indicators, such as pavement condition, volume/capacity, lane width, etc., used to determine acceptable and unacceptable highway conditions. These standards are determined consensually by Federal and State highway engineers and represent cost-effective minimum standards.

Nominal or current dollars

Actual monetary amounts with no adjustment for inflation.

Non-capital costs

Expenditures for maintenance and operations, administration, traffic law enforcement, highway safety, motor vehicle inspection, truck size and weight enforcement, and bond and note interest and redemption.

Non-user revenues

Appropriations of general funds or use of broad-based taxes such as sales, income, and property taxes.

Personal property tax

A tax based on the value of property owned by individuals, such as motor vehicles.

Present serviceability rating (PSR)

An index used to rate the quality of the pavement surface. The rating is based on a visual inspection of the surface and an assessment of ride quality compared to an established scale that ranges from 0 to 5, where 0 indicates the worst possible pavement condition and 5 represents pavement that is in perfect condition. See Figure 3-7 for a more complete definition of the PSR rating scheme.

Real dollars

Monetary amounts adjusted to remove the affects of inflation; constant dollars.

Real property tax

A tax based on the value of real estate.

Reconstruction

Construction on the approximate alignment of an existing highway where the old pavement and base are substantially removed and replaced. Slight changes may be made in the road's alignment to eliminate unsafe curves and grades. Reconstruction may include the addition of new highway capacity, where new through lanes are added in conjunction with the pavement replacement. This work may also include upgrading highway access control and operation by adding grade separations or interchanges.

3R

Resurfacing, restoration, and/or rehabilitation of an existing highway. Resurfacing is the placement of additional surface material over the existing roadway to improve its physical condition or to provide added pavement strength. Restoration and rehabilitation include all work necessary to return an existing pavement to a condition of adequate structural support. This might include joint repair, pavement stabilization, or grinding pavement in preparation for resurfacing.

Spalling

The cracking, breaking, or chipping of the pavement, usually near the edge or joint of concrete pavement.

Stub connection

A section of roadway that acts solely as a connector for some facility to a highway.

Titling tax on motor vehicles

A tax on the value of motor vehicles purchased or registered initially in the States.

Vehicle miles traveled (VMT)

An aggregate measure of travel taking place on all or part of a highway system. It is the summation of all miles traveled by all vehicles during a fixed period of time on a fixed expanse of highway.

Volume

The number of vehicles that pass over a given point of a lane or roadway during a specified time period.

Volume to capacity ratio (V/C)

A factor used in determining congestion levels on a section of highway. V/C compares the volume of traffic on a particular section of highway to its theoretical service flow for a particular time period. A V/C ratio of 0.80 or higher usually indicates congestion, with unstable traffic flow conditions. A V/C of 0.95 and greater indicates severe congestion, accompanied by traffic flow breakdown and increases in the amount of nonrecurring delay.

Weighted average motor fuel tax

The mean of all taxes on motor fuel weighted by consumption.